Weeds

VOLUME V
JULY 1957
NUMBER 3

Journal of the Weed Society of America

Weeds

Issued Quarterly by the Weed Society of America

K. P. Buchholtz, *Editor*, Dept. of Agronomy, Univ. of Wisconsin, Madison, Wisconsin.

W. C. Jacob, *Business Manager*, Dept. of Agronomy, Univ. of Illinois, Urbana, Illinois.

Editorial Committee

R. J. Aldrich, Weed Investigations Section, USDA, Rutgers Univ., New Brunswick, New Jersey

O. C. Lee, Dept. of Botany and Plant Pathology, Purdue Univ., Lafayette, Indiana.

W. C. Robocker, Weed Investigations Section, USDA, Washington State College, Pullman, Washington

W. K. Porter, Jr., Dept. of Plant Pathology, Univ. of Louisiana, Baton Rouge, Louisiana.

WEEDS is a quarterly journal published by the Weed Society of America. Editorial offices are located at the University of Wisconsin, Madison, Wisconsin. Printing is by the W. F. Humphrey Press Inc., Geneva, New York. Subscription price is $6.00 yearly for four issues; single copies $1.50. Address all communications regarding subscriptions, advertising and reprints to W. C. Jacob, Department of Agronomy, University of Illinois, Urbana, Illinois. Inquiries concerning information on manuscripts and other material for publication should be addressed to the Editorial offices. All checks, money orders and other remittances should be made payable to the Weed Society of America.

Entered as second-class matter at the post office at Urbana, Illinois with additional entry at Geneva, New York.

Table of Contents

	Page
Interaction of Temperature, Light, and Moistening Agent in the Germination of Weed Seeds. G. P. Steinbauer and Buford Grigsby	175
Influence of Various Components on the Effectiveness of 2,4,5-T Sprays. Richard Behrens	183
Rotating Disk Apparatus for the Production of Droplets of Uniform Size. George A. Roth and Gunther E. Reins	197
Effects of Herbicidal Sprays on Nitrate Accumulation in Certain Weed Species. Peter A. Frank and B. H. Grigsby	206
Effects of Amino Triazole Salts and Derivatives on Cotton Defoliation, Growth Inhibition and Respiration. C. S. Miller and Wayne C. Hall	218
Chemical Weeding and Thinning when Using Pelletized Vegetable Seeds. V. L. Guzman	227
A Critical Evaluation of the Use of Pre-emergence Herbicides for Weed Control in Cotton. W. K. Porter, Jr., C. H. Thomas, L. F. Curtis, and D. R. Melville	237
The Response of Selected Cotton Varieties to Pre-emergence Herbicides. B. A. Waddle, C. Hughes, M. N. Christiansen, and R. E. Frans	243
The Response of Certain Crops to 2,4-Dichlorophenoxyacetic Acid in Irrigation Water. Part II. Sugar Beets. V. F. Bruns	250
News and Notes	259
Sustaining Members	262
Bibliography of Weed Investigations, Oct., Nov., and Dec., 1956	263

Advertisers Index

Spraying Systems Company	ii
Carbide and Carbon Chemicals Co.	iii
du Pont de Nemours & Co.	iv
U. S. Borax & Chemical Co.	v
Standard Agricultural Chemicals Inc.	vi
Diamond Alkali Co.	vii
Chipman Chemical Co.	viii
American Cyanamid Company	ix

SPRAYING SYSTEMS

TeeJet SPRAY NOZZLES

the precision nozzle for effective spraying

Supplied in a full range of interchangeable orifice tip and strainer sizes to meet every capacity requirement. TeeJet Spray Nozzles for Weed Control by spraying make it possible to take maximum advantage of the chemical and sprayer unit. TeeJet nozzles are precision built and provide a flat spray with uniform distribution. Atomization is properly controlled to give coverage with an absolute minimum of driftage. Patented tip design, with set-back orifice opening protects precision orifice from accidental damage. TeeJet spray nozzles are built for use on spray booms and portable sprayers.

TEEJET SPRAY NOZZLE male pipe connection

TEEJET SPRAY NOZZLE female pipe connection

INTERCHANGEABLE ORIFICE TIPS flat and cone spray types

OFF-CENTER SPRAY NOZZLES

Spraying Systems Spray Nozzles with TeeJet tips are supplied in a variety of special body types to meet any unusual spraying requirement. For example, one type of off-center spray nozzle with swivel body provides a flat spray up to 35 feet wide for spraying areas with a single nozzle, that are not accessible with a boom.

SUPPLEMENTARY EQUIPMENT

Complete accessories relating to nozzle use are supplied. These include strainers, special nozzle fittings, and hand valve equipment.

TeeJet Spray Nozzles are supplied for Weed Control... as well as all other types of agricultural spraying. For complete information and reference data write for Catalog 30.

SPRAYING SYSTEMS CO.

Engineers and Manufacturers

3296 RANDOLPH STREET BELLWOOD, ILLINOIS

New CRAG BRAND MYLONE

CONTROLS SOIL FUNGI • NEMATODES • WEEDS

It's being tested on

Tobacco

Vegetable Seed Beds

Includes damping-off of tomatoes, peppers, lettuce, beets, celery, and carrots.

Ornamental Propagating Beds

Gladiolus

Here's What Mylone Controls

WEEDS

Ragweed	Bermuda grass
Peppergrass	Florida Pusley
Pigweed	Nutgrass
Crabgrass	...and many other weeds.

SOIL FUNGI

Root Rot of: Lettuce, Camellia Asparagus, Pineapple.
Fusarium Wilt of Chrysanthemums
Radish Yellows Potato Scab
Tomato *Verticillium* Wilt
Gladiolus Dry Rot
Damping-off of various vegetables

NEMATODES ... *Root-parasitic nematodes such as:*

Meloidogyne javanica
Rotylenchus reniformis
Paratylenchus minutus

NO SPECIAL SEAL NEEDED—
SIMPLY APPLY POWDER DRY OR AS WATER SUSPENSION.

CRAG Brand Mylone, 85W was formerly known as Crag Brand 974.
It is 3,5-dimethyltetrahydro-1,3,5,2H-thiadiazine-2-thione.
For test qualities of Crag Brand Mylone or for more information write to—

CRAG BRAND AGRICULTURAL CHEMICALS

CARBIDE and CARBON CHEMICALS COMPANY
A Division of Union Carbide and Carbon Corporation
30 East 42nd Street UCC New York 17, N. Y.

"CRAG" IS A REGISTERED TRADE-MARK OF UNION CARBIDE AND CARBON CORPORATION

For Agriculture and Industry . . .

Du Pont
UREA HERBICIDES

offer new economies and efficiency in killing weeds, grass and brush

"KARMEX" for weed control in asparagus, sugar cane, pineapple, potatoes, grapes, alfalfa, citrus and other crops. Also for irrigation and drainage ditch weed control. Available in two formulations: "Karmex" W monuron and "Karmex" DW diuron.

KARMEX® DL for pre-emergence weed control in cotton.

TELVAR® for industrial weed and grass control. Also in certain areas, it is recommended for brush control. "Telvar" W monuron and "Telvar" DW diuron.

The urea herbicides, products of Du Pont research, kill vegetation through the roots. Their efficiency is demonstrated by the relatively low dosages required to do the job. They can be easily applied, are non-flammable, non-volatile, non-corrosive and extremely low in toxicity.

DU PONT

Better Things for Better Living . . . *Through Chemistry*

E. I. DU PONT DE NEMOURS & CO. (INC.)

GRASSELLI CHEMICALS DEPT.

WILMINGTON 98, DELAWARE

Four easy ways to Destroy Weeds

1. UREABOR®

A nonselective, granular complex of sodium borate and substituted urea. Low application rates are a feature. Apply with the special new PCB Spreader for best results.

2. DB® Granular

A combination of 2,4-D and sodium borates. Kills deep-rooted, noxious weeds. Low application rates for maximum control with the utmost economy; use the PCB Spreader. *(Not intended for control of grass.)*

3. POLYBOR-CHLORATE®

Highly soluble; for spray or dry application. It gives a quick knock-down; destroys top growth and roots. A general nonselective herbicide.

4. Concentrated BORASCU®

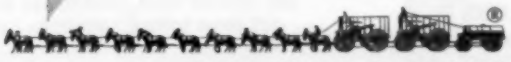
A nonselective, granular material. Apply by hand or with a mechanical spreader. Long residual action.

When you want Nonselective Herbicides

for Dependable Action

look to United States Borax & Chemical Corporation

PACIFIC COAST BORAX COMPANY DIVISION



630 Shatto Place, Los Angeles 5, Calif.
100 Park Avenue, New York 17, N.Y.

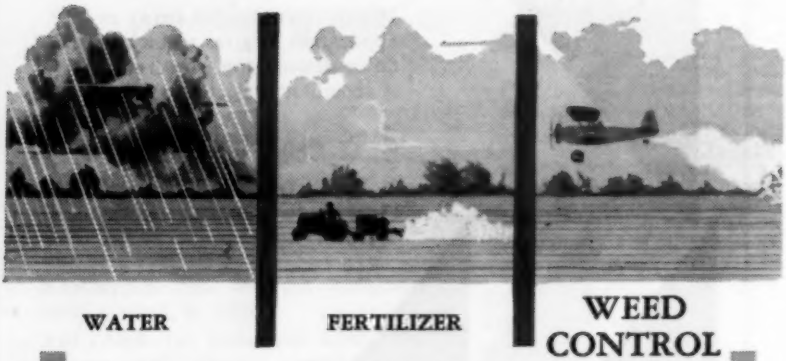
SINOX...

the standard weedkiller

Like water and fertilizer, weed control is vital to all agriculture. And SINOX formulations, products of combined field experience and laboratory research, are the *first choice* for positive weed control.

SINOX PE, for pre-emergence spraying of potatoes, beans, corn and peas; also control of winter annuals in fall seeded alfalfa, and clover.

SINOX GENERAL is a hard-hitting dinitro for clearing



WATER FERTILIZER WEED CONTROL

vines, ditches, roadsides, and general weed destruction. Useful also as a dessicant for seed alfalfa, clover, Sudan grass, flax and milo.

SINOX W is highly efficient for selective spraying of seeding alfalfa, onions, flax, peas, and grain seeded to legumes.

We are devoted to progress in weed control at Standard Agricultural Chemicals, and are helping to create a new era in weed control for *you*. Keep up to date on latest developments by checking with us directly.

STANDARD Agricultural **CHEMICALS**
INCORPORATED
1301 Jefferson Street, Hoboken, New Jersey
429 Forum Building, Sacramento, Calif.

Whatever your control problem, Diamond has the solution!

As one of the world's largest makers of herbicides, DIAMOND ALKALI has the experience and facilities to help you select the right chemical formulation for any job. Write DIAMOND ALKALI COMPANY, 300 Union Commerce Bldg., Cleveland 14, Ohio.

TECHNICALS

for formulators and processors

WEED KILLERS

2,4-D Acid • Technical Butyl-D
Technical Isopropyl-D
Technical 2-Ethyl Hexyl (Iso-Octyl)-D (Low Volatile)
Technical BEP-D (Low Volatile)

BRUSH CONTROL

Technical Butyl-T • Technical Isopropyl-T
Technical BEP-T (Low Volatile)
Technical 2-Ethyl Hexyl (Iso-Octyl)-T (Low Volatile)

READY-TO-USE FORMULATIONS

for farms, ranches, orchards, parks, homes

WEED KILLERS

*4# Mixed Amine-D • 4# Dimethylamine-D
2.67# Butyl-D • 4# Butyl-D • 6# Butyl-D
4# 2-Ethyl Hexyl (Iso-Octyl)-D (Low Volatile)
4# BEP-D (Low Volatile) • 3.34# Isopropyl-D

BRUSH CONTROL

*4# Butyl-T • 4# BEP-T (Low Volatile)
4# 2-Ethyl Hexyl (Iso-Octyl)-T (Low Volatile)
2,4-D—2,4,5-T Mixtures • 2#—2# Butyl Brush Killer
2#—2# 2-Ethyl Hexyl Brush Killer (Low Volatile)
2#—2# BEP Brush Killer (Low Volatile)

**Numbers are pounds of 2,4,5-T or 2,4-D acid equivalent per gallon.*

DIAMOND CHEMICALS

Diamond Chemicals

ATLACIDE: A chlorate weed killer ...widely used for non-selective eradication of bindweed, Canada thistle, quack grass, Johnson grass and other tough perennials. Kills roots...discourages regrowth. Applied as spray or in original dry form.

ATLACIDE WITH 2, 4-D: A combination of Atlacide and 2,4-D acid. Particularly recommended for Canada thistle control.

CHLOREA: A uniform, non-separating combination of sodium chlorate, borate and CMU. Kills *all* types of weeds and grasses. Combines the proven effectiveness of chlorate on deep-rooted weeds with the soil-surface action of CMU on shallow-rooted grasses and annual seedling growth. Has lasting residual effect to inhibit new growth. Does not create a fire hazard when used as directed. Applied dry or as a water-mixed spray. For industrial, railroad and certain agricultural uses.

CHLORAX "40": A non-separating composition of sodium chlorate and borate...for weed and grass control. Has a lasting residual effect. Does not create a fire hazard. Applied dry or as a spray.

CHLORAX LIQUID: Similar to Chlorax "40"...in liquid form for easy mixing with water.

ATLAS "A": A 40% sodium arsenite solution (4 lbs. arsenic trioxide per gal.). Destroys certain submersed vegetation in ponds and lakes. Controls crabgrass, chickweed and clover in turf. Used as general weed killer and to kill trees and stumps. Also used to kill potato vines prior to harvesting.

SODIUM ARSENITE: A powder containing 75% arsenic trioxide. Used for the same purposes as Atlas "A". Applied dry or as a spray.

2, 4-D WEED KILLERS: A complete line—Available as 2,4–D Amine and 2,4–D Ester liquids; also 2,4–D Ester dusts.

METHOXONE: Contains 2 pounds of MCP sodium salt per gallon. Used for weed control in small grains, flax, rice and grass. Controls same weeds as 2,4-D; considered safer for selective spraying.

Low Volatile 2,4,5-T
Low Volatile Brush Killer
Chloro IPC • IPC 25% Liquid

Write for Weed Control Booklets

CHIPMAN CHEMICAL COMPANY, INC.

Chicago, Ill. BOUND BROOK, N. J. Portland, Ore.
Palo Alto, Calif. . Pasadena, Tex. . Bessemer, Ala.

Manufacturers of Weed Killers Since 1912

A Cyanamid Report

Amino Triazole Weedkiller* passes first test

Amino Triazole Weedkiller has had one season of farm use for killing deep-rooted perennials. This experience justifies firmer confidence in this new chemical as a control for Canada thistle, horsetail rush, poison ivy, cattails, woody plants, and many other species. Production has been increased to meet demand in 1957.

Much interesting research yet to be done

In spite of the impressive amount of research completed during the past 4 years by State and Federal workers, we have only partial answers as to how and why this systemic herbicide does what it does to plants:

1. Why is Amino Triazole so readily absorbed into plant foliage?
2. Why is Amino Triazole translocated so readily downward and laterally throughout the plant compared to other systemic herbicides?
3. What are metabolites of Amino Triazole in the plant?
4. How does Amino Triazole destroy and interfere with the formation of chlorophyll?
5. What vital growth processes are affected, causing death of plants?
6. Why are certain species relatively so much more sensitive to Amino Triazole than others?

We will be glad to supply the latest data to those interested in working with this new herbicide.

CYANAMID

*3-amino-1, 2, 4-triazole

Send coupon for complete information and technical data

AMERICAN CYANAMID COMPANY
Agricultural Chemicals Division, Dept. W
30 Rockefeller Plaza, New York 20, N. Y.

Please send more information and technical data on Amino Triazole Weedkiller.

NAME .....

STREET .....

CITY ..... STATE .....

Weeds

JOURNAL OF THE WEED SOCIETY OF AMERICA

VOLUME V JULY 1957 NUMBER 3

Interaction of Temperature, Light, and Moistening Agent in the Germination of Weed Seeds[1]

G. P. STEINBAUER and BUFORD GRIGSBY[2]

INTRODUCTION

WEED seeds constitute one of the principal devices for invasion of weeds into new areas (2, 6, 7). Because of this fact seed laws require that the amount and kinds of weed seeds be indicated on the label attached to seeds offered for sale. In many states and provinces excessive amounts of noxious weed seeds per unit weight may be the basis for the prohibition of sale of otherwise acceptable seed.

The ability of weed seeds to persist in a viable though quiescent state in the soil for many years (3, 10) poses one of the most baffling aspects of permanent weed control. Information on the factors controlling seed longevity, the causes of dormancy, and the basic requirements for the germination of different kinds of weed seeds, is far from complete. One of the stumbling blocks to progress in these areas is the scarcity of information on how to germinate weed seeds in the laboratory. Without such information it becomes difficult to follow changes in viability of weed seeds under various storage conditions and cultural practices. Without such information it becomes difficult to distinguish dead seeds from those that are viable but dormant.

Although many references to weed seed germination have appeared in the literature of botanical science in the last 100 years, nothing comparable to the rules for seed testing (1, 5), available to laboratories testing seeds of cultivated crops, is available for those concerned with weed seed germination. Some recent progress along this line is encouraging (4, 8, 9).

Studies were initiated at Michigan State University in 1951 to work out satisfactory methods for germinating dormant and nondormant seeds of the more common weeds in the Michigan area. To date seeds of 85 species of weed plants in 15 families have been

[1]Published with approval of the Director as Paper No. 1995 Jour. Series, Michigan Agri. Exp. Sta. supported in part by RRF funds allocated by the NC–10 Technical Committee.

[2]Assoc. Prof. and Prof., resp., Dept. of Botany and Plant Pathology, Michigan State University, E. Lansing, Michigan.

studied as to germination requirements. Only a portion of the available data has been published (9) but it may be worth while to relate some of the basic requirements for weed seed germination so far observed.

GENERAL REQUIREMENTS FOR SEED GERMINATION

Statements in textbooks of botany, to the effect that seeds germinate when exposed to the proper temperature, to moisture, and aeration oversimplify the situation, and lead to a false sense of security about the ease of obtaining satisfactory and reproducible results in germination tests. The best proof of this is to be found in the fact that since the time of their inception, in the early nineteen hundreds, the Association of Official Seed Analysts and the International Seed Testing Association have had committees continuously at work assembling and revising information on the specific requirements for germination of seeds of the various cultivated plants. As will be pointed out later, the specific needs for germination of weed seeds are equally as exacting as those of cultivated plants.

An examination of the Rules for Seed Testing of the Association of Official Seed Analysts (1) and the International Seed Testing Association (5) indicates that three sets of environmental factors must be controlled accurately to insure complete germination. These are the temperature factors, the light factors, and the nature of the moistening agent. Aeration is important but it is automatically taken care of by the adequate, but not excessive, application of moisture. Dormancy is a frequent problem in the seeds of cultivated plants and even more so in those of weed plants. Fortunately the proper control of temperature, light, and moistening agents can be used to overcome the most frequent causes of dormancy.

THE TEMPERATURE FACTORS IN SEED GERMINATION

Temperature and primary dormancy.

A rather large proportion of the seeds of weed plants are dormant at maturity in that they will not germinate under conditions that later are satisfactory for germination and seedling growth. By far the most common cause of this primary dormancy is the need for complex physico-chemical changes within the seed known as "after-ripening". The need for after-ripening is especially common in such families as the Gramineae, Rosaceae, Cruciferae, Caryophyllaceae, and Polygonaceae. However, wide divergences exist within groups as to the degree of dormancy. Thus, as shown in Table 1, corn cockle, *Agrostemma githago,* germinates promptly under a variety of conditions, soon after harvest. Other examples of species not temperature sensitive are *Tragopogon pratensis* and *Taraxacum officinalis.* Soapwort, *Saponaria officinalis,* in the same family as Agrostemma germinates only after exposure of the moist seeds to 5° C. for one or two weeks prior to the higher temperatures. In most instances the need for after-ripening can be overcome by one of

these "prechill" treatments for a week or two. In some instances, as in certain members of the Rosaceae and Polygonaceae, the prechill must be extended to several weeks or months to be effective.

The need for after-ripening usually disappears after the seeds have been in dry storage for a few weeks. Typical of this behaviour is that of chess, *Bromus secalinus,* shown in Table 2. *Saponaria officinalis,* however, retains the need for the prechill treatment for several years, as indicated in Table 3.

Table 1. Germination of *Agrostemma githago* seed.

Temperature	Percentage germination at 6 days[1]
5° C. constant	0**
10° C. constant	100
15° C. constant	99
20° C. constant	100
25° C. constant	97
5° C. 16 hrs.—30° C. 8 hrs.	89
15° C. 16 hrs.—30° C. 8 hrs.	100
20° C. 16 hrs.—30° C. 8 hrs.	98

[1]Based on 4 x 100 seeds on two blotters in petri dish with water and darkness.
**Significantly different from base treatment (20° C.) at 1% level only at 6 days, not later.

Table 2. Germination of *Bromus secalinus* seed.

Temperature	Percentage germination at 9 days[1]	
	Test started 1 day from harvest	Test started 1 month from harvest
15° C. constant	90	98
20°C. constant	4**	98
30° C. constant	0**	96
20° C. 16 hrs., 30° C. 8 hrs.	1**	99
5° C. 1 wk., then 20° C. constant	99	96
5° C. 1 wk., then 20° C.–30° C.	97	97

[1]Based on 4 x 100 seeds on two blotters in petri dish with water and darkness. Total days required for completion of test 9, even where the first 7 are used in prechill.
**Significantly different from base treatment (15° C.) at 1% level.

Table 3. Germination of seeds of soapwort, *Saponaria officinalis.*

Temperature	Percentage germination at days from harvest[1]		
	7 days	300 days	1095 days
15° C. constant	0**	0**	0**
20° C. constant	0**	0**	0**
30° C. constant	0**	0**	0**
20° C. 16 hrs., 30° C. 8 hrs	31**	12**	10**
5° C. 1 wk., then 20°–30° C.	99	97	82

[1]Based on 4 x 100 seeds on two blotters in petri dish with water and darkness. Final counts at 21 days.
**Significantly different from base treatment (5° C. 1 wk. then 20°–30° C.) at 1% level.

Optimum temperature range for germination.

The optimum range of temperatures within which germination occurs varies with the age, physiological state, and kind of seed. Thus during the first few weeks after harvest the seeds of *Bromus*

secalinus will not germinate at temperatures in excess of 15° C., although they germinate freely at 20° C., 25° C., and 30° C. after about one month of dry storage. This behaviour has been noted in seeds of many grasses and other plants. The extremes of temperature for germination vary from a minimum of 5° C. for *Agrostemma githago, Ambrosia artemisiifolia,* and *Camelina microcarpa* to a maximum of around 35° C. for *Amaranthus retroflexus.* Most weed seeds germinate within the range of 20° C. to 30° C.

Thermoperiodicity.

Weed seeds germinating in nature do so in the presence of daily alternations between low night and high day temperatures. It should not be surprising, therefore, to find that by far the great majority of seeds germinate more promptly with daily alternation of temperatures, than with constant temperatures. Out of 85 species considered in the present study, over 80 percent showed better germination with daily temperature alternations than with constant temperatures. Many seeds, typified by wormseed mustard, *Erysimum cheiranthoides,* germinate very little if any, at constant temperatures, as illustrated in Table 4. Other examples are the seeds of *Phytolacca*

Table 4. Germination of seeds of wormseed mustard, *Erysimum cheiranthoides.*

Treatment	Percentage germination at 5 days[1]
20° C. constant, water[2]	0**
20° C. constant, 0.2% KNO_3[2]	0**
30° C. constant, water[2]	6**
30° C. constant, 0.2% KNO_3[2]	7**
20° C.–30° C., water[2]	67**
20° C.–30° C., 0.2% KNO_3[2]	98
20° C.–30° C., water, light[3]	94
20° C.–30° C., water, dark[4]	53**
20° C.–30° C., 0.2% KNO_3, light[3]	95
20° C.–30° C., 0.2% KNO_3, dark[4]	86**

[1]Based on 4 x 100 seeds on two blotters, in petri dishes.
[2]Darkness except during transfers and counts.
[3]100 foot-candles illumination from white fluorescent bulb.
[4]Complete darkness by wrapping petri dishes in aluminum foil, final counts only.
**Significantly different from base treatment (20–30° C., 0.2% KNO_3, light) at 1% level.

americana, Potentilla monspeliensis, and *Oenothera biennis.* This situation is not unique for weed seeds since seeds of over 75 percent of cultivated plants behave in similar manner (1, 5).

As shown in Table 5 the need for alternation of temperatures is not transitory but may persist in some species for several years.

The number of cycles of temperature alternation necessary to induce germination may be as few as one in *Lepidium virginicum* and *Erysimum cheiranthoides* but usually is greater than this.

Induction of secondary dormancy.

Seeds capable of germination may be thrown into dormancy by unfavorable environmental factors. The most widely publicized case is that of lettuce seed, in which exposure of imbibed seeds to 30° C. for extended periods, may induce "secondary dormancy".

Table 5. Germination of seeds of wormseed mustard, *Erysimum cheiranthoides*, showing persistence of thermo-periodicity.

Treatment	Percentage germination at 5 days[1]	
	1955 seed	1951 seed
20° C., constant, water	0**	0**
20° C., constant, 0.2% KNO_3	0**	2**
30° C., constant, water	6**	0**
30° C., constant, 0.2% KNO_3	7**	9**
20° C.–30° C., water	67**	47**
20° C.–30° C., 0.2% KNO_3	98	80

[1]Based on 4 x 100 seeds on two blotters in petri dishes with darkness except during transfers and counts.
**Significantly different from base treatment (21° C.–30° C., 0.2% KNO_3) at 1% level.

This behaviour is also found in certain weed seeds, particularly those of plants in the Cruciferae family. Thus the seeds of *Erysimum cheiranthoides*, exposed to 30° C. for some time prior to temperature alternations may show a marked reduction in germination, as illustrated in Table 6. The degree of dormancy depends on the length of exposure to the unfavorable temperature.

Table 6. Germination of seeds of wormseed mustard, *Erysimum cheiranthoides*, to show induction of secondary dormancy and importance of temperature in the primary thermocycle.

Temperature	Percentage germination at 6 days[1]
30° C. three days, then 20° C.–30° C.	15**
30° C. two days, then 20° C.–30°C.	14**
30° C. one day, then 20° C.–30° C.	25**
30° C. 8 hrs., then 20° C.–30°C.	42*
20° C. 16 hrs., 30° C. 8 hrs., then 20° C.–30° C.	61

[1]Based on 4 x 100 seeds on two blotters in petri dishes, water, darkness except during transfers.
*Significantly different from base treatment (20°–30° C., 20°–30° C.) at 5% level.

The Light Factor in Germination

Although the majority of seeds germinate as well in darkness as light some germinate poorly or not at all when completely deprived of light. These seeds are probably restricted in their germination under natural conditions to such times as the seeds are brought to the soil surface, and the soil remains moist long enough for completion of germination. About 35 percent of the seeds tested germinated more rapidly and uniformly in light than darkness. Illumination from a white fluorescent bulb in the germinator, yielding about 100 foot-candles of light was supplied during the high temperature phase of the temperature alternation. As is well known from the literature of seed germination, the length of light exposure necessary to insure maximum germination varies from a few minutes to several hours. It is interesting to note that some seeds such as *Erysimum cheiranthoides*, Table 4, may germinate well even though no supplementary illumination is supplied, and yet germinate much less when light is completely withheld by wrapping the petri dishes in aluminum foil. In the first instance the low light

requirement is probably met by the brief exposure to light while the seeds are being transferred from one germinator to another during temperature alternations, and during the time that preliminary counts of seedlings are made during the tests.

THE TYPE OF MOISTENING AGENT

Seeds germinating in nature are moistened by the soil solution, containing many dissolved organic and inorganic substances. While it is customary to test most seeds in laboratories, using tap water or distilled water, many examples might be given in which dilute solutions of nitrate or other inorganic sources of nitrogen greatly enhance germination. The use of such solutions is recommended in the Rules for Seed Testing (1, 5) for testing certain seeds such as many of the grasses, crucifers, etc. Approximately 50 per cent of the different kinds of weed seeds studied, germinated better with nitrate solution than water, especially soon after harvest, when embryo dormancy is common. In many instances, typified by the seeds of pokeweed, *Phytolacca americana,* very little germination could be secured with water, even when all other factors seemed to be favorable, but excellent germination was obtained when potassium nitrate solution was used as a moistening agent.

INTERACTION OF TEMPERATURE, LIGHT, AND MOISTENING AGENT

From the foregoing discussion it should be evident that various, carefully controlled combinations of the above factors are necessary to insure complete germination of viable seeds of the many different kinds of plants included in the term weeds. The interaction of these three variables has been discussed in detail elsewhere (11). In a few seeds such as *Erysimum cheiranthoides,* Table 4, the light requirement may be largly overcome by the use of alternating temperatures combined with nitrate solution, but in others, such as *Phytolacca americana,* all three factors, alternating temperature, light, and nitrate solution must be present to obtain any appreciable germination. On the basis of the 85 kinds of weed seeds studied, by far the largest number of seeds will germinate when given an alternation of temperatures, are supplied with light, at least for a short exposure, and a dilute solution of nitrate is used as a moistening agent. Such conditions are supplied in nature when seeds are on the soil surface during periods of sufficient moisture. It is probably for this reason that seeds of many of our weeds, such as the small-seeded crucifers, remain dormant when an inch or two below the soil surface but germinate readily when the soil is disturbed and they are brought to the surface, particularly during periods of adequate soil moisture.

METHODS OF CONTROLLING TEMPERATURE, LIGHT, AND MOISTURE DURING WEED SEED GERMINATION TESTS

Temperature. Since provisions for alternations of temperature are required one must have available two germinators or ovens that can

be set and controlled at the temperatures needed. The seeds can then be transferred daily from the low temperature, usually 16 hours, to the high temperature, 8 hours. Although it is possible to purchase germinators that automatically change temperatures these are quite expensive. Temperatures below room temperature can be obtained by use of water jacketed incubators cooled with running water. It is also possible to convert electric refrigerators to low temperature germinators. Small, inexpensive space heaters, equipped with a fan can be used to supply heat which in turn is controlled by a thermo-regulator. Most space heaters carry too much current for efficient use. Replacement of the heating coil with one of lower wattage is desirable. One of 250 watts is recommended. This amount of current can be handled conveniently directly through a thermo-regulator of the "Fenwal" type without use of relays.

Moisture control. Proper control of moisture is one of the most critical factors in obtaining consistent results in seed germination. Excess watering must be avoided, particularly for small seeds. Adequate moisture must be maintained at all times. Many different devices and substrates are used in seed testing laboratories to solve this problem. After comparing several of these the use of closed petri dishes in which two layers of standard blotting paper are placed has been adopted. In use the blotters are saturated and then drained until no more water drips from the inclined sheets, after which they are placed in the bottoms of the petri dishes. Even seeds as large as those of corn cockle and radish germinate well in petri dishes on top of blotters. The use of petri dishes, rather than open blotters makes possible the use of dry ovens, as germinators. Moisture must of course be checked daily and added as necessary. Large seeds such as *Xanthium* spp. and *Ambrosia trifida* may require use of sand or upright paper towels, although large petri dishes could be used if the seeds were presoaked several hours in water and then placed between blotters in the dish.

When potassium nitrate solution is used it is applied in a concentration of 0.2% and used only for the initial moistening of the media.

Light. Light of approximately 100 f. c. can be best supplied with a cool white fluorescent bulb suspended in the germinator. Incandescent lamps tend to supply too much heat and they supply light too rich in the far red part of the spectrum, which may be inhibitory to germination as in the case of *Lepidium virginicum* (11). If complete exclusion of light is desired the petri dishes may be wrapped in aluminum foil. Final counts only are made since brief exposure of seeds during counting operations may satisfy the light requirement of certain seeds.

Dormancy. Although many factors may contribute to seed dormancy the most common cause is the need for "after-ripening". The period of after-ripening is shortened in most seeds by placing the seeds in a moist substratum at 2° to 10° C. for varying lengths of time. If the seeds are to be germinated in petri dishes these may be

placed in the refrigerator, care being exercised to keep the seeds moist during the treatment.

Special methods. Some seeds such as velvet leaf, *Abutilon theophrasti* (4) may require special methods to soften the seed coats. These include such treatments as the use of boiling water, mechanical scarification and use of corrosive acids. Such methods require very careful manipulation, particularly where acids are used, to avoid injury to the operator and to the seed embryo. In some instances several treatments may have to be combined to overcome factors which operate together to delay germination.

LITERATURE CITED

1. ASSOC. OFF. SEED ANAL. Rules for testing seeds. PROC. ASSOC. OFF. SEED ANAL. 44:31–78. 1954.
2. CRAFTS, A. S. Weed control: applied botany. Amer. Jour. Bot. 43:548–556. 1956.
3. DARLINGTON, H. T. The seventy-year period for Dr. Beal's seed viability experiment. Amer. Jour. Bot. 38:379–381. 1951.
4. EVERSON, LEROY. Preliminary studies to establish laboratory methods for the germination of weed seeds. Proc. Assoc. Off. Seed Anal. 39:84–89. 1949.
5. INTERN. SEED TESTING ASSOC. International rules for seed testing. Proc. International Seed Testing Assoc. 19:3–79. 1954.
6. MUENSCHER, C. H. Weeds. The Macmillan Co., New York 1955.
7. RIDLEY, H. N. The dispersal of plants throughout the world. L. Reeve Co., Ltd., Kent 1930.
8. ROGERS, B. J., and STEARNS, F. W. Preliminary studies on the germination of weed seeds. Proc. North Central Weed Control Conference, p. 7. 1955.
9. STEINBAUER, G. P., GRIGSBY, BUFORD, CORREA, LUIS, and FRANK, PETER. A study of methods for obtaining laboratory germination of certain weed seeds. Proc. Assoc. Off. Seed Anal. 45:48–52. 1955.
10. TOOLE, E. H., and BROWN, E. Final results of the Duvel buried seed experiment. Jour. Agr. Res. 72:201–210. 1946.
11. TOOLE, E. H., HENDRICKS, S. B., BORTHWICK, H. A., and TOOLE, VIVIAN K. Physiology of seed germination. Ann. Rev. of Plant Physiology 7:299–324. 1956.

Influence of Various Components on the Effectiveness of 2,4,5–T Sprays[1]

RICHARD BEHRENS[2]

MANY factors influence the effectiveness of a herbicidal spray. The importance of some, such as herbicide formulation and carrier, has been demonstrated, while the influence of others is either in doubt or has not been established. Since selective herbicides are being applied as sprays to millions of acres annually, more information on factors influencing their effectiveness in spray applications would be of value.

The importance of herbicide concentration, droplet size, spray volume and droplet spacing on the effectiveness of the phenoxy herbicides is open to question. Evidence is contradictory in the case of droplet size and spray volume, while herbicide concentration and droplet spacing have received little attention. Of the components listed above, droplet size and spacing received major attention in this study, while spray volume and herbicide concentration were considered secondarily.

In 1946, Smith (17) published the first study concerned with droplet size and spray volume involving a herbicide of the phenoxy group. He concluded that moderate to large droplets, with volume rates from 10 to 20 ml. per square yard, gave maximum effectiveness when aqueous solutions of the ammonium salt of 2,4–dichlorophenoxyacetic acid (2,4–D) were sprayed on kidney bean plants. Fisher and Young (8) reported that preliminary evaluations of aerial applications of 2,4–D and 2,4,5–trichlorophenoxyacetic acid (2,4,5–T) indicated that coarse and medium droplet sizes were equally or possibly more effective than fine droplets on the basis of mesquite response. Mullison (13) found no difference in the response of young bean plants when a given amount of 2,4–D was applied as one large drop or several small drops. On the other hand, Ennis and Williamson (6) indicated that growth regulators applied as small droplets (below 0.1 mm diameter) were more inhibitory to several plant species than larger droplets (above 0.3 mm diameter). Dayhoff (5) obtained similar results under conditions of high humidity. Hellquist (9), Sexsmith (16), and Buchholtz (3) all agree that an equivalent amount of 2–methyl–4–chlorophenoxyacetic acid (MCPA) used in low gallonage sprays was more toxic to peas than when used in high gallonage sprays.

The experiments reported herein utilize equipment that maintains over-all plant coverage similar to that obtained with conventional spray equipment, yet gives more precise control of droplet size than has been obtained in previous work. In abstract form, partial results of this study have been published elsewhere (1, 2).

---

[1]Contribution of the Field Crops Research Branch, ARS, USDA in cooperation with the Texas Agri. Exp. Sta. and the Texas Eng. Exp. Sta.

[2]Plant Physiologist, Field Crops Research Branch, ARS, USDA, Department of Plant Physiology and Pathology, Texas A. & M. College, College Station, Texas.

METHODS AND MATERIALS

The whirling disc apparatus described in an accompanying paper (15) was used to apply droplets of uniform size to mesquite and cotton seedlings that were grown in 6-inch flower pots. Droplet size was controlled and spray volume calculated as described by Roth and Reins (15). Plants in each pot were adequately thinned before application to eliminate the possibility of plants shielding each other from full exposure to the herbicide treatment. Various formulations of 2,4,5–T were used as the herbicide in all of the tests described herein. Application rates are on a 2,4,5–T acid equivalent basis.

Mesquite seedlings, from two to six months old, were used in many of the tests. The number of plants utilized per treatment varied from test to test and will be listed with the pertinent tables and figures. In most instances the response of mesquite to the various applications will be expressed as per cent of stem tissue killed. These data were obtained by determining the length of dead stem tissue of the plants in a treatment, dividing by the total stem length of plants receiving the treatment, and multiplying by one hundred. Supplementary readings were made on per cent leaf and total plant kill. Data from these measurements are not always listed since they indicated the same trends in plant response.

When cotton seedlings were used, they were treated when the cotyledons were fully expanded, usually ten days after planting. Plants were harvested about two weeks after treatment. The fresh weight of tissue produced during the two-week period was a good indication of plant response.

EXPERIMENTAL PROCEDURE AND RESULTS

Droplet size, droplet spacing, and spray volume were the dependent variables in this study of the effect of various components on the efficiency of herbicidal sprays. Herbicide concentration, a fourth component, is dependent on and inversely proportional to spray volume when a constant rate of herbicide application is maintained. Three possibilities for altering these factors that were used in these experiments are illustrated in Figures 1, 2, and 3.

First, droplet size was changed while a constant spray volume was maintained. Enlargement of the droplet size required an increase in droplet spacing as illustrated in Figure 1. By this means, the combined influence of droplet size and spacing on the effectiveness of 2,4,5–T sprays was determined in the first group of experiments.

Second, the droplet spacing was varied while droplet size remained constant. The necessary reduction in spray volume and increase in herbicide concentration as droplet spacing becomes greater is illustrated in Figure 2. A second group of tests was completed under these conditions which allowed the determination of droplet spacing effects on plant response free from the influence of droplet size.

Third, droplet size was changed while droplet spacing remained

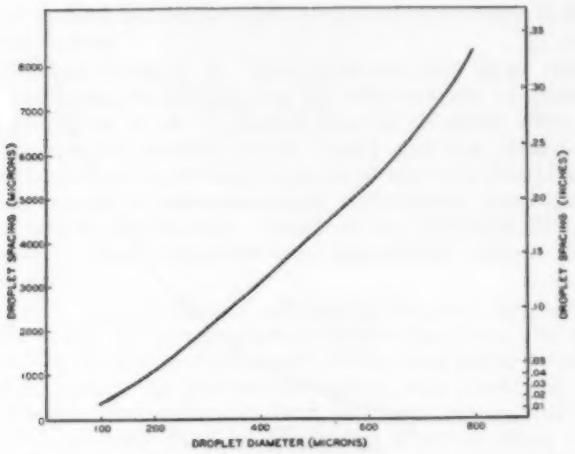


Figure 1. Relationship of droplet spacing to droplet diameter at a constant 4 gpa spray volume.

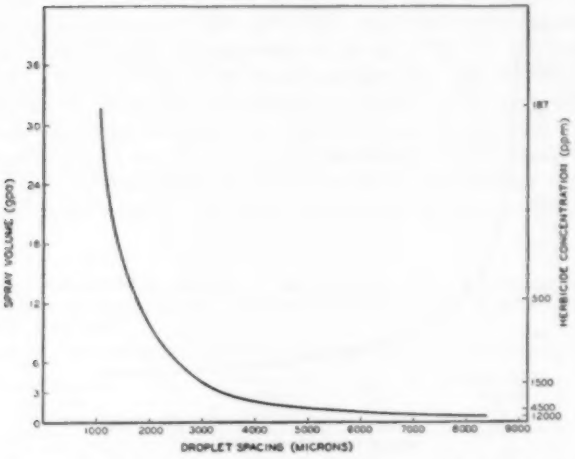


Figure 2. Relationship of spray volume and herbicide concentration to droplet spacing when 0.10 lb/A herbicide is applied in droplets with a diameter of 400 microns. Herbicide concentration is inversely proportional to spray volume.

constant. Spray volume was increased and herbicide concentration decreased as droplet size was enlarged (Figure 3). In this way, droplet size effects on plant response were examined in a third group of tests without interference from droplet spacing.

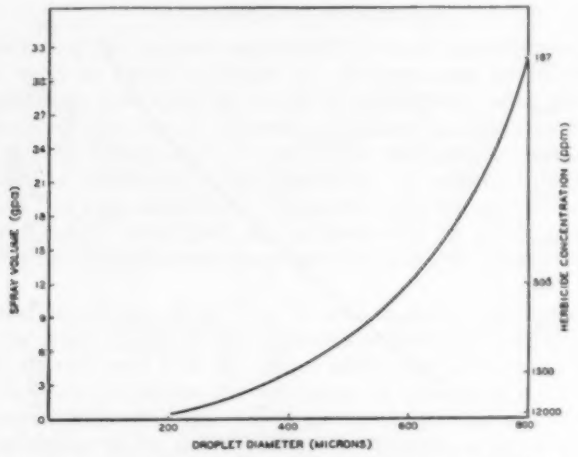


Figure 3. Relationship of spray volume and herbicide concentration to droplet diameter when 0.10 lb/A of herbicide is applied at a deposition rate of 72 droplets per square inch.

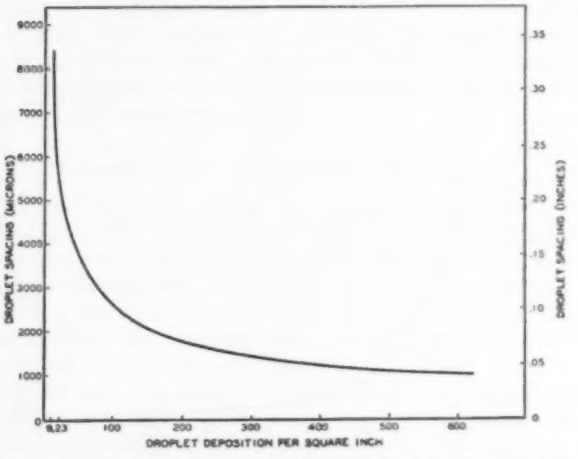


Figure 4. Relationship of droplet spacing to the droplet deposition rate. Droplet spacing expressed in inches as well as microns.

Droplet spacing is a function of the droplet deposition rate per unit area. The decrease in droplet spacing as the droplet deposition rate increases is illustrated by Figure 4. In presenting data, the droplet deposition rate will be listed rather than droplet spacing, since it was based on actual counts while droplet spacing figures are estimates mathematically derived from the droplet deposition rate.

However, it should be emphasized that droplet spacing is the factor under examination.

Smith (17) and Ennis et al. (7) have shown that spray retention is an important factor in influencing the effectiveness of growth regulating sprays. Ennis et al. (7) found that oil droplets were retained by all plant species studied, while many did not retain aqueous droplets. Oil carriers were used in most of the tests described below to eliminate possible influence from differential retention. However, there was no indication, visual or on the basis of measured plant response, that retention was incomplete when the water carrier was used.

The use of a non-phytotoxic oil carrier in most applications removed absorption and penetration as important variables since the oil droplets penetrated mesquite and cotton leaf tissue within a few seconds after contact. In one instance phytotoxic diesel oil was compared to the non-phytotoxic oil. In a few tests, water and oil-water emulsion carriers were used to determine whether plant responses were comparable to those obtained with the oil carriers when changes were made in the various spray components under study.

Combined influence of droplet size and spacing when spray volume is constant.

In the first experiment, spray volume was held constant at 4 gpa, while droplet diameters of 200, 400, 600, and 800 microns were used, which produced droplet deposition rates of 575, 72, 23, and 9 per square inch, respectively. The triethanolamine salt of 2,4,5–T was applied in water at rates equivalent to 0.05, 0.10, and 0.20 lb/A. Applications of large droplets at low droplet deposition rates had little injurious effect on the mesquite seedlings (Table 1). The smallest droplet size, 200 microns in diameter at a deposition rate of 575 droplets per square inch, was most damaging to the seedlings, while

Table 1. Mesquite seedling response to applications of the triethanolamine salt of 2,4,5-T in water carrier at a spray volume of 4 gpa. Readings made 30 days after treatment.

Droplet diameter microns	Droplets applied no/sq in	2,4,5-T lb/A	Stem tissue killed[1] %	Foliage killed[1] %
200	575	0.05	8	8
200	575	0.10	10	11
200	575	0.20	24	26
400	72	0.05	0	0
400	72	0.10	0	1
400	72	0.20	10	7
600	23	0.05	0	0
600	23	0.10	0	0
600	23	0.20	1	1
800	9	0.05	0	0
800	9	0.10	0	0
800	9	0.20	1	0

[1]Average of 30 plants.

Table 2. Mesquite seedling response to applications of the propylene glycol butyl ether ester of 2,4,5-T in 25 per cent emulsion carrier at a spray volume of 4 gpa. Readings made 30 days after treatment.

Droplet diameter microns	Droplets applied no/sq in	2,4,5-T lb/A	Stem tissue killed[1] %	Foliage killed[1] %	Plants killed[1] %
200	575	0.05	55	70	10
200	575	0.10	73	89	33
200	575	0.20	79	96	53
400	72	0.05	39	42	3
400	72	0.10	49	67	3
400	72	0.20	63	86	30
600	23	0.05	19	27	0
600	23	0.10	25	38	0
600	23	0.20	33	57	3

[1]Average of 30 plants.

droplets with a diameter of 400 microns at a deposition rate of 72 droplets per square inch were approximately half as injurious.

A similar test was completed using the propylene glycol butyl ether (PGBE) ester of 2,4,5–T with a 25 per cent diesel fuel in water emulsion as carrier and droplet diameters of 200, 400, and 600 microns. To stabilize the emulsion, 4.5 per cent 1–hydroxyethyl–2–heptadecenyl glyoxalidine[3] and 2 per cent Tergitol Non-anionic NPX[3] were added. This herbicide mixture was much more toxic to the mesquite seedlings than the preceding combination. The data in Table 2 again shows that small droplets at high droplet deposition rates (i.e. close spacing) were more effective, while larger droplets at lower deposition rates (i.e. greater spacing) were progressively less effective in inducing mesquite response.

In the final test of this series, the PGBE ester of 2,4,5–T was applied at a single rate, 0.10 lb/A, using droplet diameters of 200, 400, 600, and 800 microns with diesel fuel as carrier at a spray volume of 4 gpa. Mesquite seedling response to this treatment was approximately equal to that obtained when the 25 per cent emulsion carrier was used (Table 3). Again a reduction of droplet size and the associated increase in the droplet deposition rate resulted in greater effectiveness of the herbicide application.

Table 3. Mesquite seedling response to applications of the propylene glycol butyl ether ester of 2,4,5-T in diesel oil carrier at a spray volume of 4 gpa. Readings made 30 days after treatment.

Droplet diameter microns	Droplets applied no/sq in	2,4,5-T lb/A	Stem tissue killed[1] %	Foliage killed[1] %	Plants killed[1] %
200	575	0.10	64	81	33
400	72	0.10	45	52	17
600	23	0.10	36	34	11
800	9	0.10	20	21	0

[1]Average of 18 plants.

[3]Sample supplied by the Carbide and Carbon Chemicals Company.

To summarize, all of the tests in this group show that droplet size, droplet spacing, or a combination of these factors have a vital influence on the effectiveness of herbicidal spray applications. Herbicide concentration and spray volume were not involved since they remained constant in this group of tests.

It is interesting to note that the diesel fuel carrier was equal in effectiveness to the 25 per cent diesel fuel-water emulsion. The rapid contact injury due to diesel fuel carrier described by Hull (10), which reduced the effectiveness of herbicide applications to mesquite seedlings in his experiments, was not apparent at the 4 gpa volume of application used in this test.

Influence of droplet spacing when droplet size remained constant.

By decreasing spray volume and increasing herbicide concentration as droplet spacing was increased, as illustrated in Figure 2, it was possible to study the droplet spacing component in 2,4,5–T spray applications without the influence of droplet size. A droplet diameter of 400 microns was maintained while droplet deposition rates of 9, 23, 72, 216, and 575 per square inch were used. The droplet deposition rate series was identical to that of the previous tests, except that a rate of 216 droplets per square inch was added. Since spray volumes up to 32 gpa were necessary, a non-phytotoxic oil was employed to eliminate the possibility of contact injury due to the carrier at the high volumes. The butoxyethoxy propanol (BEP) ester replaced the PGBE ester which was not totally miscible in the non-toxic oil carrier.

Data showing the response of mesquite and cotton seedlings to the applications described above are listed in Tables 4 and 5. Both

Table 4. Cotton response to 2,4,5-T (BEP ester in non-toxic oil carrier) as influenced by changes in droplet deposition rate when a 400 micron droplet diameter was maintained. New growth of seedlings (25 plants per treatment) was harvested 15 days after application of 0.03 lb/A of 2,4,5-T.

Droplets applied no./sq in	Per cent reduction in fresh weight of new cotton growth
575	88
216	81
72	72
23	48
9	39

Table 5. Mesquite response to 2,4,5-T (BEP ester in non-toxic oil carrier) as influenced by changes in droplet deposition rate when a 400 micron droplet diameter was maintained. Stem kill measurements were made on 24 plants per treatment 30 days after application of 0.10 lb/A of 2,4,5-T.

Droplets applied no./sq in	Stem tissue killed %
575	80
216	74
72	68
23	41
9	29

species exhibited increased reaction to the herbicide as the droplet deposition rate was increased. Response curves based on data from Tables 3, 4 and 5 illustrate the very rapid increase in herbicidal effectiveness as the droplet deposition rate was increased from 9 to 72 per square inch (Figure 5). At deposition rates above 72 per square inch the slope of the plant response curves was greatly reduced. The break in the response curves at the 72 droplet per square inch deposition rate was evident in each test. This similarity in response, regardless of whether droplet size was changed (Data from Table 3) or held constant (Data from Tables 4 and 5) illustrates the major role of droplet spacing in the determination of the effectiveness of a herbicidal spray application.

In a supplementary test using mesquite seedlings, the possibility of reduced herbicidal effectiveness due to rapid contact injury caused by a phytotoxic carrier was investigated. The test was similar to those described above, except that diesel fuel was used as a carrier for the PGBE ester of 2,4,5–T. Plant response was found to increase when deposition rates up to 72 droplets per square inch (4 gpa spray volume) were used, but declined slightly at higher droplet deposition rates (12.5 and 32 gpa spray volume), as shown in Figure 6. This contrasted with the results of the earlier test, Figure 5, in which a diesel fuel volume of 4 gpa was maintained, for mesquite seedling response gradually increased as the droplet deposition rate became greater, in that instance. This difference was considered to be due to the rapid contact kill of leaves which was evident 24 hours after 12.5 and 32 gpa of diesel oil had been applied. However, even at the greatest spray volume, 32 gpa, the phytotoxic effect of diesel fuel did not induce any drastic decline in herbicidal effectiveness. In all probability, the reduction in plant response associated with high

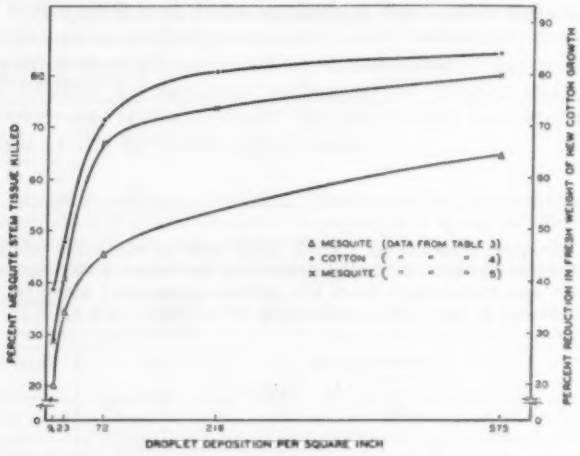

PERCENT MESQUITE STEM TISSUE KILLED
PERCENT REDUCTION IN FRESH WEIGHT OF NEW COTTON GROWTH
DROPLET DEPOSITION PER SQUARE INCH
9.23
72
218
575
Δ MESQUITE (DATA FROM TABLE 3)
○ COTTON (" " " 4)
× MESQUITE (" " " 5)

Figure 5. Plant response to 2,4,5–T as influenced by changes in the droplet deposition rate.

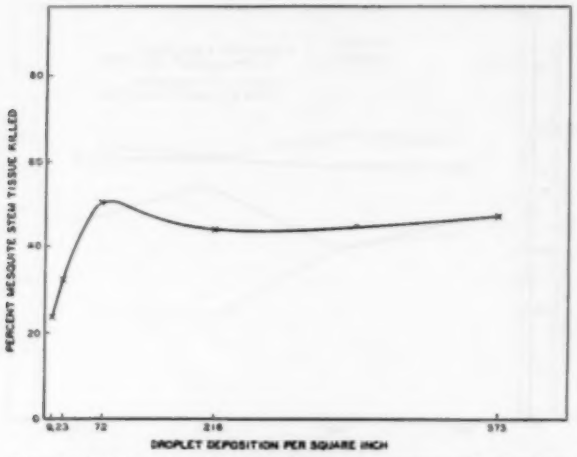


Figure 6. Mesquite (24 seedlings per treatment) response to 0.1 lb/A of 2,4,5–T in a phytotoxic carrier (PGBE ester in diesel fuel) as influenced by changes in the droplet deposition rate (droplet spacing) when a droplet diameter of 400 microns was maintained. At deposition rates of 9, 23, 72, 216 and 575 droplets per square inch, spray volumes were 0.5, 1.3, 4.0, 12.0 and 32.0 gpa, respectively.

spray volumes of diesel fuel was partially offset by increased herbicide effectiveness resulting from closer droplet spacing.

Influence of droplet size when droplet spacing remains constant.

Evidence has been presented showing that droplet spacing has a considerable influence on the effectiveness of a herbicidal spray application. However, the possibility that droplet size may also play a part in determining the effectiveness of a herbicidal spray application was not eliminated by the foregoing tests. The droplet size factor was examined without the influence of droplet spacing by controlling droplet spacing, spray volume, and herbicide concentration, as discussed previously (Figure 3). Mesquite and cotton seedlings were included in this series of tests.

Using droplet diameters of 200, 400, 600, and 800 microns, the BEP ester of 2,4,5–T was applied in a non-phytotoxic oil carrier. In the first tests, a deposition rate of 72 droplets per square inch was maintained, while herbicide application rates of 0.05 and 0.10 lb/A were used on mesquite seedlings. Though plant response was somewhat variable when the 0.05 lb/A herbicide application rates were used, there was no definite trend in herbicidal effectiveness as droplet size was changed (Figure 7). At the 0.10 lb/A rate of application, plant response was constant regardless of the droplet size used.

In a similar test, a deposition rate of 23 droplets per square inch, considerably below the rate required to attain a high level of herbicidal effectiveness, was applied to mesquite and cotton seedlings.

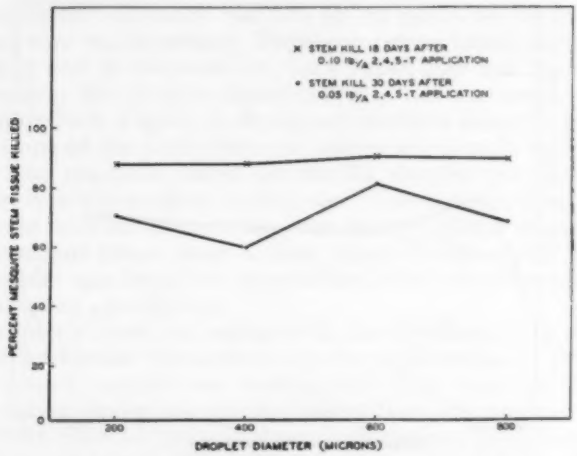


Figure 7. Mesquite (25 seedlings per treatment) response to 2,4,5–T (BEP ester in non-toxic oil carrier) as influenced by changes in droplet size when a constant deposition rate of 72 droplets per square inch was maintained.

On mesquite, a 2,4,5–T application rate of 0.05 lb/A was maintained. At the sub-optimum droplet deposition rate, an increase in herbicidal effectiveness was evident when larger droplets were used (Figure 8). When cotton replaced mesquite as the test plant, the 2,4,5–T application rate was reduced to 0.03 lb/A. Results differed from those obtained when mesquite was used in that cotton seedling response was not affected by droplet size changes.

Plant response in this group of tests shows that droplet size is not a major factor in determining the herbicidal effectiveness of a spray application. It may have some influence in instances where the droplet deposition rate is sub-optimal. However, this is not always true, as indicated by the results of a sub-optimal droplet deposition rate on cotton.

The uniformity of plant response in this group of tests as herbicide concentration and spray volume underwent great changes (herbicide concentration from 187 to 12,000 ppm and spray volume from 0.5 to 32.0 gpa) is evidence that these factors are not directly involved in determining the herbicidal effectiveness of a spray application. However, it should be recognized that under certain conditions both may be of importance, indirectly. Spray retention may be affected by spray volume while changes in herbicide concentration often alter the physical characteristics of a spray, which in turn, may affect herbicide absorption.

A supplementary test was included to determine possible droplet size effects on plant response when the herbicide solution does not readily penetrate the epidermal tissues of the leaves. A herbicide solution composed of the triethanolamine salt of 2,4,5–T in water

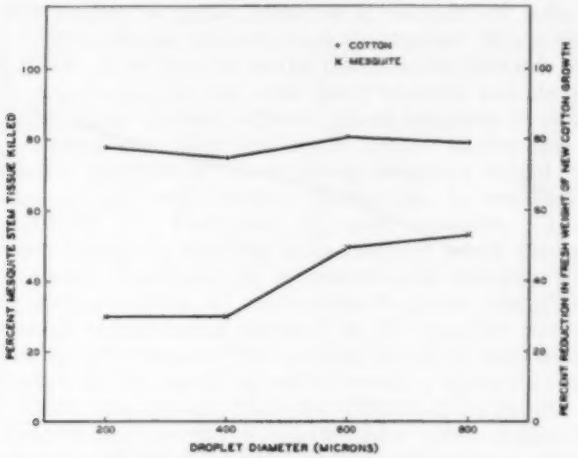


Figure 8. Plant response to 2,4,5–T (BEP ester in non-toxic oil carrier) as influenced by droplet size when a 23 droplet per square inch deposition rate was maintained. Cotton seedlings (50 plants per treatment) were harvested 15 days after application of 0.03 lb/A of 2,4,5–T. Stem kill measurements on mesquite (24 plants per treatment) were made 30 days after treatment with 0.05 lb/A of 2,4,5–T.

was used because preliminary tests indicated that it was absorbed slowly. The herbicide was applied at 0.30 lb/A to mesquite using droplet sizes and spray volumes similar to those in the preceding tests, and with a deposition rate of 72 droplets per square inch. A wetting agent, Dynawet[4], was added at a concentration of 0.20 per cent to all herbicide solutions to eliminate possible differences in wetting characteristics of the droplets as spray volume was reduced and herbicide solutions became more concentrated. The general trend was toward a reduction in plant response as droplet size and spray volume were decreased (Figure 9).

DISCUSSION

In the foregoing experiments, droplet spacing was demonstrated to have considerable influence on the herbicidal effectiveness of 2,4,5–T applications to mesquite and cotton seedlings. This finding suggests that a limited area of leaf tissue surrounding each droplet functions in some process essential for herbicidal activity. Since movement of the phenoxy herbicides is necessary before plant responses will develop (11, 14, 18), it is likely that translocation is the process involved. The association of carbohydrates with the translocation of the phenoxy compounds is well known (4, 11, 12). It seems probable that the function of cells in the area surrounding a droplet

[4]Sample supplied by Dow Chemical Company, Midland, Michigan.

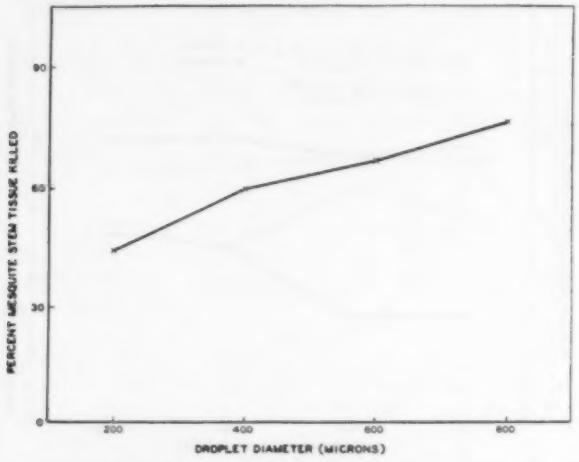


Figure 9. Mesquite (24 plants per treatment) response to 2,4,5–T (0.30 lb/A of the triethanolamine salt in water carrier) as influenced by droplet size when a 72 droplet per square inch deposition rate was maintained. Stem kill measurements made 30 days after treatment.

is the production of carbohydrate which is necessary for translocation of the 2,4,5–T applied in the droplet. Assuming the above, information on droplet spacing can be used to estimate the leaf area involved in movement of the 2,4,5–T deposited in an individual droplet. The maximum droplet spacing that will produce a high level of herbicidal activity would approximate the diameter of the leaf area involved in translocation of herbicide from a droplet. A decisive break in plant response curves at a deposition rate of 72 droplets per square inch suggests that the equivalent droplet spacing, 3100 microns, approximates the diameter of the leaf area that participates in translocation of 2,4,5–T from a single droplet.

A moderate increase in plant response was observed when closer droplet spacings were used. This increase may have been due to the better coverage of localized areas of the leaf which were missed owing to the random distribution of droplets at the 3100 micron spacing.

At a greater than optimum spacing, 5200 microns, larger droplets induced increased plant response in the case of mesquite. Such an increase might be expected since larger droplets tend to spread over a greater leaf area, and thus, expand the total leaf surface involved in absorption and translocation of herbicide. It should be emphasized that this response to droplet size was evident only when droplet spacing exceeded that needed for maximum herbicidal effectiveness, and plant response was well below the levels attained when closer droplet spacing was used.

Within the treatment ranges and species used in these tests, droplet size, spray volume, and herbicide concentration had little direct

effect on the degree of plant response if oil carriers were used to eliminate differences due to herbicidal absorption. When absorption becomes a factor, as in the case of the triethanolamine salt of 2,4,5–T applied in water, droplet size and spray volume assume some importance. The trend toward reduced plant response as droplet size and spray volume were decreased seems logical in the case of water because smaller droplets at lower spray volumes would evaporate more rapidly, which would restrict absorption. In contrast to these results, Buchholtz (3), Hellquist (9), and Sexsmith (16) reported that increased injury to canning peas resulted when the spray volume was reduced. Buchholtz (3) attributed this response to the better wetting characteristics of concentrated sprays, and the proportionally greater surface area covered by the smaller droplets produced at low spray volumes. The wetting characteristics of all sprays were held constant by means of added wetting agent in this test on mesquite, which may account for the difference in results.

While droplet size and spray volume have little direct influence on the herbicidal effectiveness of a spray application, indirectly they are involved because droplet spacing (number of droplets deposited per unit area) is a function of the size of droplets and the volume of spray applied. Present trends in the development of spray equipment are toward the application of larger, more uniform droplets at reduced spray volumes. As progress is made in this direction, a point may be reached where droplet spacing must be considered. However, the wide droplet spectrums produced by presently available spray equipment assures adequate droplet spacing at the spray volumes now being used.

SUMMARY

Droplet size, droplet spacing, spray volume, and herbicide concentration were studied to establish their relative importance in determining the effectiveness of 2,4,5–T spray applications.

Droplet spacing was found to be of major importance in the determination of herbicidal effectiveness. An average droplet spacing of 3100 microns, equivalent to a deposition rate of 72 droplets per square inch, was considered the maximum distance that would maintain a high level of herbicidal effectiveness when 2,4,5–T was applied to mesquite and cotton.

Except for some minor effects, droplet size, spray volume, and herbicide concentration had no direct influence on plant response under the conditions imposed in this group of tests. In the case of water carrier at the 72 droplet per square inch deposition rate, larger droplets applied at high volumes were found to be slightly more effective on mesquite; presumably due to the longer period of moist contact which increased herbicide absorption.

The effectiveness of 2,4,5–T applications was reduced when diesel fuel carrier was used at the high spray volumes of 12.5 and 32 gpa. The reduced effectiveness was attributed to the phytotoxicity of diesel fuel, which caused rapid leaf kill at high spray volumes and, consequently, limited 2,4,5–T translocation.

ACKNOWLEDGMENTS

The author would like to express his appreciation to personnel of the Aircraft Research Center, Texas Engineering Experiment Station, College Station, Texas, for adapting their whirling disc apparatus so that it could be used to apply droplets to plants. The assistance of G. E. Reins in making the droplet applications to plants is gratefully acknowledged.

LITERATURE CITED

1. BEHRENS, R. The effect of herbicide droplet size and other variables on mesquite control. Texas Agric. Aviation Conf., Fifth Annual, Sect. D, pp. 1–4. 1956.
2. ———, FISHER, C. E., and MEADORS, C. H. Response of mesquite seedlings to 2,4,5–T as influenced by droplet size and spray volume. Proc. Southern Weed Conference, p. 166. 1956.
3. BUCHHOLTZ, K. P. Some factors affecting the tolerance of peas to MCP and other growth regulating herbicides. Weeds 3:331–341. 1954.
4. DAVIS, G. E., and SMITH, O. Physiological studies of the toxicity of 2,4–D. Proc. Northeastern Weed Control Conf., pp. 92–101. 1950.
5. DAYHOFF, E. E. The influence of droplet size upon the effectiveness of herbicidal application of 2,4–D in beans. M. S. Thesis, Texas A & M College, College Station, Texas. pp. 1–31. 1956.
6. ENNIS, W. B., and WILLIAMSON, R. E. Studies on the influence of droplet size upon the inhibitory effectiveness of growth regulating sprays. (Abstr.) Ann. Meetings of the Amer. Soc. Agron., p. 31. 1951.
7. ———, ———, and DORSCHNER, K. P. Studies on spray retention by leaves of different plants. Weeds 1:274–286. 1952.
8. FISHER, C. E., and YOUNG, D. W. The effect of herbicide droplet size on the control of mesquite when applied by airplane equipment. Proc. North Central Weed Control Conf., pp. 84–86. 1950.
9. HELLQUIST, A. H. Spraying technique and the use of chemical weed killers. Vaxtodling 7:78–94. 1952.
10. HULL, H. M. Studies on herbicidal absorption and translocation in velvet mesquite seedlings. Weeds 4:22–42. 1956.
11. LINDER, P. L., BROWN, J. W., and MITCHELL, J. W. Movement of externally applied phenoxy compounds in bean plants in relation to conditions favoring carbohydrate translocation. Bot. Gaz. 110:628–632. 1949.
12. MITCHELL, J. W., and BROWN, J. W. Movement of 2,4–D acid stimulus and its relation to translocation of organic food materials in plants. Bot. Gaz. 107:393–407. 1946.
13. MULLISON, W. R. The effect of droplet size upon herbicidal effectiveness of plant growth regulators. Down to Earth 9(2):11–13. 1953.
14. RICE, E. L. Absorption and translocation of ammonium 2,4–dichlorophenoxyacetate by bean plants. Bot. Gaz. 109:301–314. 1948.
15. ROTH, G. A., and REINS, G. E. Rotating disc apparatus for the production of droplets of uniform size. Weeds (In press).
16. SEXSMITH, J. J. Effect on canning peas of amine 2,4–D and MCP applied at different rates and spray volumes. Res. Report, North Central Weed Control Conf., p. 80. 1954.
17. SMITH, H. H. Quantitative aspects of aqueous spray applications of 2,4–D acid for herbicidal purposes. Bot. Gaz. 107:544–551. 1946.
18. WEINTRAUB, R. L., and BROWN, J. W. Translocation of exogenous growth regulators in the bean seedling. Plant Phys. 25:140–149. 1950.

Rotating Disk Apparatus for the Production of Droplets of Uniform Size

GEORGE A. ROTH and GUNTHER E. REINS[1]

INTRODUCTION

IT has long been recognized that one of the inherent problems in spray application, particularly with airplanes, is that of droplet size control. It is not generally known which droplet sizes or ranges of droplet sizes are the most effective biologically for the various types of treatments. It is known, however, that excessively large droplets result in a serious waste of material, and that very small droplets present a serious drift problem. For these reasons, spray droplet size and the range of sizes in a given spray have become important criterions in evaluating a spray distribution pattern.

Distribution pattern measurement studies have been conducted at the Aircraft Research Center, Texas Engineering Experiment Station, College Station, Texas, since 1950. The technique used employs a series of chemical balances to weigh the spray as it is deposited at ground level (5). While this method yields deposit rate data quickly and with little laboratory work, it does not in itself give droplet size distribution information. To provide this additional and necessary information collecting surfaces, usually a parchment-type paper, are placed immediately adjacent to the weighing units. Then, with a soluble dye added to the spray fluid, a pattern of spots is obtained which represents the droplet sizes that yield the weight measurement. The spot pattern cannot be used directly to determine droplet distribution without a knowledge of the relationship between the diameters of the spherical droplets that produced them. This relationship, or spread factor, can only be determined by producing droplets of known or measurable spherical diameters and comparing them with the corresponding spot diameters on the collecting medium used. With the spread factor known, spot measurement, tabulation, and computation can yield droplet distribution and deposit rate.

The rotating disk device described herein was built primarily as a uniform droplet source for the determination of spread factors with various spray fluids and collecting media. It has been used extensively for this purpose and with this usage have come additional possibilities for its utilization. These include the possibilities of study of droplet evaporation, the effect of additives (emulsifiers, sticking agents, etc.) on droplet size, and the relationship of droplet size, dosage rate and coverage to biological effectiveness in the use of herbicides and insecticides.

[1]Aircraft Research Center, Texas Engineering Exp. Sta., Texas A. & M. College System, College Station, Texas.

DESCRIPTION OF EQUIPMENT

Mechanical System. The device built at the Aircraft Research Center for the production of uniformly-sized droplets incorporates a rotating aluminum disk powered by a pneumatic motor.

Two interchangeable disks with 4-inch and 8-inch diameters, respectively, are used to obtain the desired range of droplet diameters. The disk is supported on a shaft and bearing assembly as shown in the schematic drawing in Figure 1. The pneumatic motor is attached below the bearing housing, providing a self-aligning direct drive to the disk.

The pneumatic motor is operated from an external air compressor. From the air compressor through a large air manifold the air is fed into a pressure regulator as shown in Figure 1. From the regulator the air passes on to the pneumatic motor; as can be seen from the schematic drawing, an air pressure gauge and a large surge tank are connected into this line. The surge tank is installed to damp

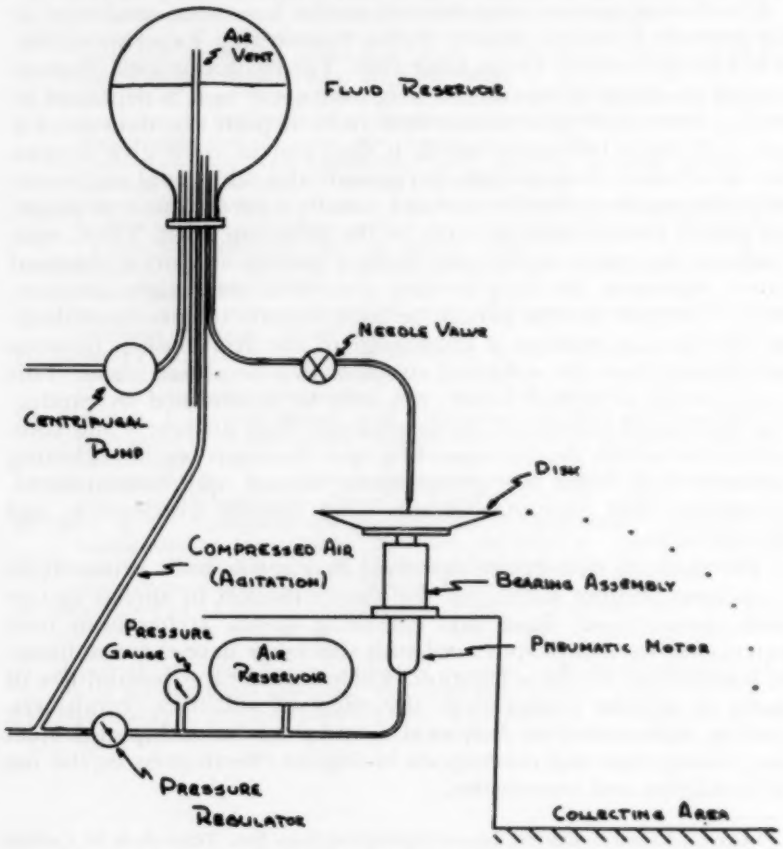


Figure 1. Schematic drawing of rotating disk device.

small pressure variations that might occur in the air supply system.

Speed control of the pneumatic motor is obtained by pressure regulation of the air supply. Disk rotational speed is measured with a stroboscopic tachometer.

Around the rotating disk is placed a cylindrical metallic shield containing an adjustable aperture. By means of this aperture the direction and duration of the droplet emission can be controlled. In addition it has also been found necessary to shield the droplet projection area from any local air currents; otherwise, the droplet deposit points are quite scattered, particularly with the smaller droplets.

Fluid Supply System. During the preliminary operation of the rotating disk a constant-head type of fluid supply system, similar to that described by Yates (6), was used. This was soon modified to the system as shown in Figure 1.

The fluid reservoir is a large, inverted, vented flask located sufficiently above the level of the rotating disk that small changes in fluid level result in a negligible change in head pressure. From the flask fluid feeds down to a needle valve which controls fluid flow. From the needle valve the fluid flows through a drawn glass nozzle onto the center of the rotating disk.

Supplementary additions were made to this basic fluid supply system as occasion warranted. First, a small electric centrifugal pump was incorporated to fill the flask and provide mild agitation of the fluid by circulation through the system. Later, as emulsions were used, it was found necessary to increase the fluid agitation; this was done pneumatically by the controlled bleeding of air through the liquid.

OPERATION

Liquid fed onto the center of the rotating disk is forced to the disk periphery by centrifugal force and is dispersed tangentially. The droplet formation has been classified by Hinze and Milborn (2) into (1) direct droplet formation, (2) ligament formation, and (3) film formation. In the first instance, the fluid flow rate is low and droplets form singly at the disk periphery. In the second case, at higher flow rates, the droplet formation is from one or more fluid ligaments forming at the disk periphery. Further increase in flow rate results in the third type of droplet formation where the fluid leaves the disk in the form of a film or sheet with subsequent breakup into droplets.

While no attempt was made to study droplet formation, it was noted that in working with the aluminum rotating disk the greatest uniformity of droplets was obtained with low flow rates after the disk surface had been initially well polished with powdered pumice and then thoroughly wetted. With Diesel oil, which has a good wetting tendency on aluminum, a liquid film formed over the disk surface. With water, which has a poor wetting tendency on aluminum, rivulets formed on the disk surface. For water, some other material besides aluminum should be used or a coating might be

applied to the disk surface to provide a better wetting tendency. For a particular disk speed and fluid it was apparent that there was a critical flow rate which, if exceeded, resulted in a decrease in droplet uniformity with a substantial increase in very fine droplets of a mist-like size. While this is not desirable it is acceptable under certain conditions, because the very small droplets can be removed by controlled air movement around the disk. Also, since the projection distances of the droplets are dependent upon their mass and air drag (smaller droplets are deposited closer to the disk), droplets of a size other than those desired can be screened out at the collecting surface.

DETERMINATION OF DROPLET SPHERICAL DIAMETER

Water. One of the major problems in the use of the rotating disk has been that of collecting the droplets produced and retaining them in spherical form long enough to be measured. Fortunately, with water this has been relatively simple. By using an immiscible fluid of slightly less density than water the water droplets can be immersed and retained in spherical form.

In practice a small petri dish was coated with a film of G.E. Dri-Film No. 9987. This liquid, when applied to the inside of the dish and wiped dry, provided a non-wetting surface that prevented the droplets from spreading on the glass surface. Next, a layer of mineral oil, approximately $^3/_{16}$ inch thick, was placed in the bottom of the petri dish. Then a thin layer of petroleum-base solvent (Varsol) approximately $1/8$ inch thick, was placed on top of the mineral oil layer. It was observed that there was less break-up of droplets when the petroleum-base solvent layer (sp. gr. .79–.82) was placed on top of the mineral oil layer (sp. gr. .88–.94). The droplets, when caught in this medium, would gradually settle to the bottom of the petri dish but remain substantially spherical in shape. The petri dish containing mineral oil and solvent and the water droplets was then placed under a microscope where actual spherical droplet diameters were measured with a calibrated ocular micrometer.

Oil. The measurement of the diameters of oil droplets presented some difficulty. Methyl alcohol was used as an immersion fluid in the procedure described above. The oil droplets retained their spherical shape but diminished in size with time. It was found, however, that with timed diametric measurements the rate of droplet dissipation could be determined. From this information the original diameter could be computed and results were obtained which were in agreement with the results of later measurement techniques.

One of these techniques employed magnesium oxide-coated glass slides. The slides were coated with the magnesium oxide by passing them back and forth over burning magnesium ribbon until a deposit of the desired thickness was obtained. The thickness of the layer varied between one and two millimeters, depending on the spherical droplet diameter. Previous work (4) had shown that the crater or hole left by the penetration of the droplet through the magnesium

oxide film had a direct relationship with the diameter of the droplet. On the basis of this work the droplet diameter could be determined by measuring the crater diameter (microscope and ocular micrometer) and multiplying this measurement by 0.86. Incidental checks of the validity of this factor by the more absolute method described below indicated that the factor might vary from 0.85 with 200 micron droplets to 0.99 for droplets 625 microns in diameter. It was noted however that as the droplet size was increased above a 400 micron diameter, the droplets would tend to bounce from the slide and leave two or more craters on the magnesium oxide layer. Consequently, this method was employed only for small droplets (below 400 microns) where no visible bouncing occurred.

The most successful technique for measuring oil droplets utilized a gelatinous matrix as described by Hurtig and Perry (3). This matrix was prepared by mixing the following constituents and heating them until the mixture was completely dissolved and homogeneous: Water, 40 ml; glycerine, 40 ml; gelatin, 3 gms; triethanolamine, 10 ml; and liquid soap, 10 ml. The droplets were caught in the warmed matrix which had been placed on glass slides; then another slide or cover slip coated with the matrix was placed over the first slide with spacers of suitable thickness between. The droplets then became surrounded entirely by the matrix and were retained indefinitely in their spherical form for measurement.

RELATIONSHIP OF DROPLET DIAMETER TO DISK SPEED

Since the droplet diameter for any particular liquid is dependent upon the disk rotational speed and diameter, information pertaining to two disk diameters (4 inch and 8 inch) is presented in Figure 2. From Fraser and Eisenklam's work (1) it was found that the ratio of the droplet diameters produced by the two disks was inversely proportional to the square root of their respective diameters provided the disk speed and flow rate were the same. This relation correlated well with values obtained by Yates (6). No direct comparisons can be made with values obtained by our two rotating disks since the flow rates were not measured. The tests from which these data were obtained were made with fluid flow rates that were relatively small and yielded the greatest droplet uniformity.

SPREAD FACTOR DETERMINATION

Since techniques to measure spherical droplet diameter were available, it was not difficult to determine the relationship between spherical diameter and spot diameter for any collecting surface.

So that spray droplet patterns from field applications could be parchment type of paper.[2] To do this the spray fluid was colored with an inert soluble dye. For water, DuPont Paper Blue R Conc[3]

[2]Patapar 27–21T, Paterson Parchment Paper Co., Bristol, Pennsylvania.

[3]E. I. DuPont de Nemours & Co., Organic Chemical Dept., Dyestuffs Division, 1261 Spring Street, N. W., Atlanta, Georgia.

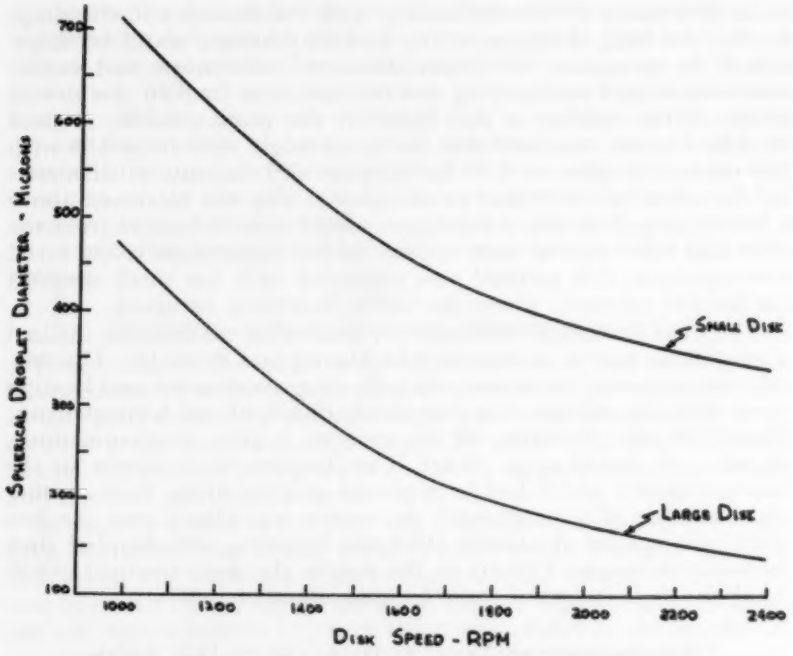


Figure 2. Disk speed vs. spherical droplet diameter for water.

(2 gms/gallon) was used. For Diesel oil, Calco Oil Red[4] and DuPont Paper Blue R Conc (2 gms ea/gallon) were used. Then for each of a number of disk speeds and droplet sizes, the matrix-covered slides or oil-filled petri dishes and the paper samplers were placed on the collecting surface so that spherical droplets and spots were obtained simultaneously. The diameters of both the droplets and spots (after drying) were measured with microscope and ocular micrometer. The ratio of the measured spot diameter to the droplet spherical diameter then became the spread factor. The relationship between droplet diameter and spread factor for water and No. 2 Diesel oil with the parchment paper is shown in Figure 3. It will be seen that the spread factors were not constants but varied with droplet diameter.

As a matter of interest, several typical spot bands are shown in Figure 4. The width of these bands represents the uniformity of droplet size (± 5% diameter), since under a given set of conditions the distance from the rotating disk to the point of droplet contact is dependent upon droplet diameter.

PLANT TREATMENT

The treatment of plants with a uniform application of droplets of a particular diameter presented several problems.

[4]American Cyanamid Company, New York, N. Y.

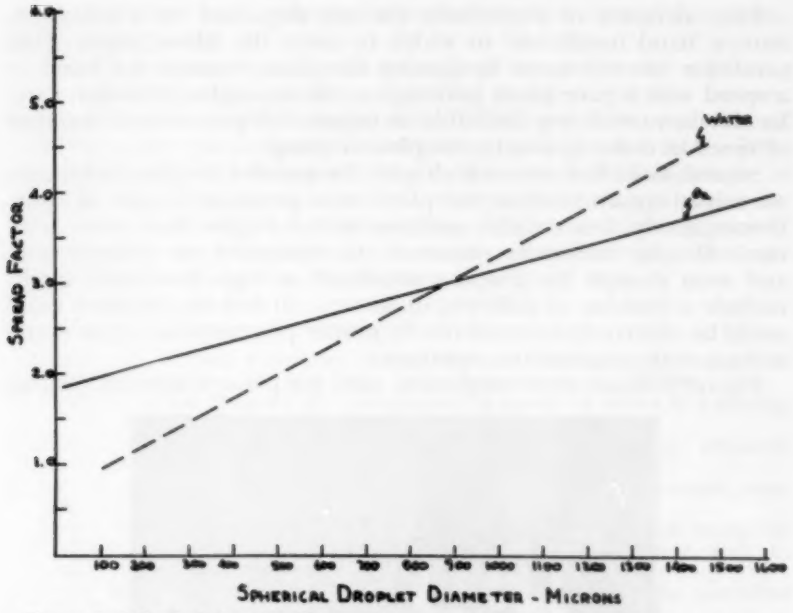


Figure 3. Spherical droplet diameter vs. spread factor on parchment paper.

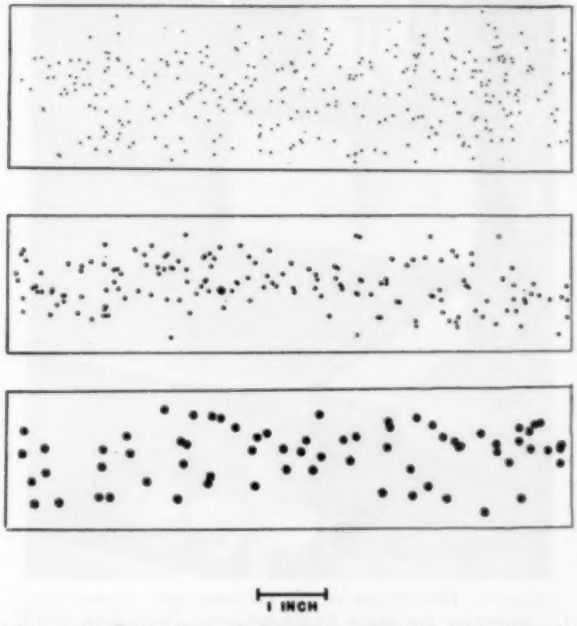


Figure 4. Illustration of droplet uniformity and deposit band for water droplets of 400, 600, and 800 micron spherical diameter.

First, droplets of a uniform size are deposited in a relatively narrow band insufficient in width to cover the whole plant. This condition was overcome by passing the plant through the band at a speed which gave plant coverage at the desired application rate. In certain cases it was desirable to repeat this procedure a number of times in order to obtain complete coverage.

Second, fluid flow rates which gave the greatest droplet uniformity were inadequate to treat the plant in a practical length of time. Consequently, less droplet uniformity but higher flow rates were used. Droplet trajectory, however, is dependent on droplet size; and even though the droplets produced at high flow rates might include a number of different diameters, all but the primary band could be effectively screened out by proper placement of a horizontal surface with a concentric aperture.

Figure 5 shows the arrangement used for plant treatment (shields

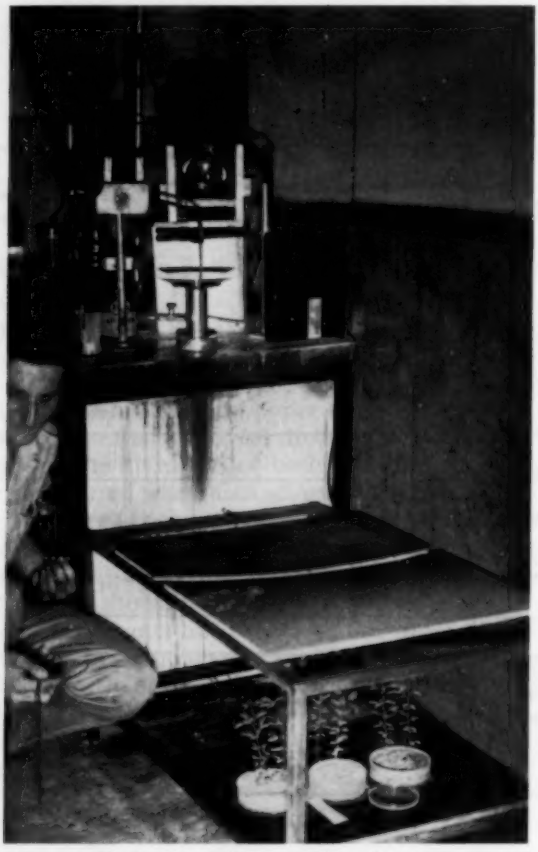


Figure 5. Illustration of the rotating disk arrangement including the plant treatment area. (Shields removed for photographic purposes.)

around the disk and treatment area have been removed for photographic purposes).

The plants were moved at a controlled rate below the screening surface and through a curtain of falling droplets. As may be seen from the figure, a paper sampler and oil-filled petri dish were placed adjacent to the plants being treated. Droplets deposited in the petri dish were measured in spherical form as a check for uniformity of droplet size. The spot pattern on the parchment-type paper indicated the uniformity of plant coverage. With the droplet diameter known, the actual deposit rate in terms of gallons per acre was computed after counting the droplets in a given area.

LITERATURE CITED

1. FRASER, R. P., and EISENKLAM, PAUL. Research into the performance of atomizers for liquids. Jour. Imp. Coll. Chem. Engr. Soc. 7:52–68. 1953.
2. HINZE, J. O., and MILBORN, H. Atomization of liquids by means of a rotating cup. Jour. Appl. Mech. 17:145–153. 1950.
3. HURTIG, H., and PERRY, A. S. Slide coatings for aerosol droplet collection and preservation. Jour. Econ. Ent. 43:952–954. 1950.
4. MAY, K. R. The measurement of airborne droplets by the magnesium oxide method. Jour. Sci. Insts. 27:128–130. 1950.
5. WEICK, FRED. Experimental agricultural airplane and distribution measuring station. First Annual Texas Agricultural Aviation Conference. Sect. D, pp. 1–17. 1952.
6. YATES, W. E. An analysis of atomization by the rotating disk for controlled droplet size. M.S. thesis, University of California. 1951.

Effects of Herbicidal Sprays on Nitrate Accumulation in Certain Weed Species[1]

PETER A. FRANK and B. H. GRIGSBY[2]

SINCE the advent of the new and, generally, more efficient herbicides, a great deal of research has been done and a voluminous literature presented concerning their uses and possible mechanisms of action. The more obvious effects of the chemicals have been described at length but the basic physiological mechanisms remain relatively undefined.

The rapid adoption of new herbicides by agriculturists, home owners and others, has been attended with some criticism. Adverse criticisms have arisen because research agencies have not conducted extensive experiments concerning the possible harmful effects in humans and in animals. Extended exposure to the chemicals and the products of the treated plants may be harmful. Herbicides may also bring about the elaboration by plants of a toxic substance, or the accumulation of a substance ordinarily present in non-toxic concentrations.

In recent years there have been numerous reports of death of livestock foraging on members of the genera *Prunus* and *Sorghum* treated with 2,4–D and 2,4,5–T. Members of these two genera are known to accumulate glucosides which, upon hydrolysis, may produce hydrocyanic acid, sometimes in concentrations lethal to livestock. It has been postulated that abnormal quantities of hydrocyanic acid which caused livestock losses may be produced by treated plants (5). However, data from some experiments indicate that treated plants do not accumulate enough glucosides to produce large amounts of hydrocyanic acid (7, 9).

There have also been a number of cases reported where livestock losses were attributed to nitrate poisoning from forage high in nitrates (2, 11, 12, 13, 14, 17). Livestock grazing on herbicide-treated vegetation (4) were believed to have ingested toxic quantities of nitrate which had been accumulated by the plants as a result of chemical treatment. The assumption that crop and weed plants may accumulate nitrate as a result of herbicidal treatment is a new development which requires careful experimental study.

Willard (18), in discussing the indirect effects of herbicides, cites numerous reports of ordinarily unpalatable weeds becoming palatable to livestock following herbicidal treatment. The effect of herbicides on the palatability of these weeds could be a factor contributing to the nitrate poisoning of livestock. However, many of the weeds tested were found to contain toxic quantities of nitrate in both the treated and untreated state.

---

[1]This material is adapted from a thesis by the senior author presented to the school of Graduate Studies, Michigan State University. Journal Article 1922 from the Michigan Agricultural Experiment Station.

[2]Asst. Prof. Agronomy, University of Idaho, Moscow and Prof. of Botany, Michigan State University, East Lansing, respectively.

A study of the problem of nitrate accumulation was initiated during the summer of 1953 and continued through the summer of 1954. The data presented are from analyses made in each season. A group of weeds commonly found in cropped and pasture land in Michigan was selected for study. This group included certain weeds known to accumulate high concentrations of nitrate as well as others suspected of having contributed in some manner to livestock losses. These weeds were treated with various herbicides and nitrate analyses were made at regular intervals following treatment in an attempt to determine the effects of the treatments upon the nitrate content.

REVIEW OF LITERATURE

High levels of nitrate in green weeds and crops, as well as in cured feeds, may often have disastrous consequences. The first recognized case of nitrate poisoning of livestock was in 1888 and was reported, along with a number of other cases, in 1895 (16). The losses were traced to the feeding of both green and cured corn fodder and hay. The nitrate content, determined as potassium nitrate, amounted to as much as 25 percent of the dry weight and the salt crystals could be observed readily with the naked eye. In more recent years, nitrate poisoning from oat hay (2, 10, 17), hay containing pigweed (11), sorghum (11, 12) and sugar beet tops (13) has been reported.

Poisoning from ingestion of high-nitrate plants is due to the reduction of nitrate to nitrite by microorganisms in the intestinal tracts of animals. The nitrite is taken into the blood stream where it combines with oxyhemoglobin to form methemoglobin. The latter is incapable of giving up its oxygen to the tissues and thus causes asphyxia (2). Bradley et al. (2), have determined the minimum lethal dose to be 25 grams of potassium nitrate per one hundred pounds of animal weight. At this level, a five hundred-pound animal would have to eat but five and one-half pounds of oat hay containing 5 percent nitrate to become fatally poisoned.

Stahler and Whitehead (15) report a case in which several hundred acres of sugar beets on seven farms were accidentally treated with 2,4–D. Samples of beet leaves from the seven farms, together with several samples from untreated fields of adjacent farms, were analyzed for nitrate. The average nitrate level in the untreated beet leaves, calculated in terms of potassium nitrate, was found to be 0.22 percent of the dry weight. The nitrate levels in the treated leaves ranged from 1.81 percent to 8.77 percent, all of which were considered above the minimum lethal concentration. The authors also have observed that 2,4–D has a profound effect on the nitrate content of sugar beet leaves. These results indicate that 2,4–D may affect the nitrate level of beet leaves to the extent that considerable losses could be expected if the leaves were fed to livestock.

Lambs-quarters, pigweed and smartweed when treated with 2,4–D were cited by Willard (18) to be very high in nitrate while the controls contained very little. This was thought to be due to the 2,4–D retarding the assimilation of nitrates into protein. These weeds, as well as sugar beet leaves, have been found by various

other workers to accumulate nitrates in toxic concentrations even when not treated with 2,4–D.

Fertig (4) studied the effect of 2,4–D and MCPA on the accumulation of nitrate in lambs-quarters, ragweed, pigweed and curled dock but was unable to obtain conclusive results.

The absorption and elaboration of nitrogenous nutrients in plants is dependent upon such external factors as the pH and nitrate concentration of the growth medium, and the relative availability of various mineral solutes. Such factors as light, temperature, moisture and oxygen supply also are important. Of equal importance are the availability of carbohydrates within the plants and the stage of growth of the plants. Some of these factors may possibly be modified by the application of herbicides to the plants. Applications of 2,4–D and related compounds are known to have a considerable effect on the metabolism and growth processes of plants. This effect could bring about changes in the rates of photosynthesis, root growth, nutrient absorption and transpiration. Because of the numerous factors influencing the uptake and assimilation of nitrates, considerable variations in the nitrate levels should be expected, not only in plants growing under normal conditions, but also in plants treated with herbicides.

MATERIALS AND PROCEDURES

The species of weeds studied were selected on the basis of availability, occurrence in pastured areas, and reports concerning the ability of certain of the weeds to accumulate nitrate. All of the species were found growing on or bordering the muck farm used for other weed control investigations. The following species were selected:

1. *Amaranthus retroflexus* L.
2. *Ambrosia elatior* (L.) Descourtils
3. *Chenopodium album* L.
4. *Cirsium arvense* (L.) Scop.
5. *Eupatorium maculatum* L.
6. *Impatiens biflora* Walt.
7. *Poa pratensis* L.
8. *Polygonum Convolvulus* L.
9. *Polygonum Persicaria* L.
10. *Prunus virginiana* L.
11. *Sambucus canadensis* L.
12. *Solanum Dulcamara* L.
13. *Spiraea alba* Du Roi
14. *Thalictrum dioicum* L.

Some of the more commonly used herbicides, which were believed to offer differences in physiological activity, were used. These were:

1. Isopropyl ester of 2,4–dichlorophenoxyacetic acid (2,4–D)
2. Butyl ether ester of 2,4,5–trichlorophenoxyacetic acid (2,4,5–T)
3. Sodium salt of 2–methyl–4–chlorophenoxyacetic acid (MCPA)
4. Alkanolamine salt of dinitro–o–sec–butyl–phenol (DNBP)

5. Isopropyl–N–(3–chlorophenyl) carbamate (CIPC)
6. Diethanolamine salt of maleic hydrazide (MH)

The weeds were treated with sub-lethal dosages of herbicide applications. This was done to prevent excessive deterioration or death of the plants during the period in which analyses were to be made. The spray mixtures were applied in a volume of 80 gallons of water per acre, except a few which were applied with a volume of 40 gallons of water per acre. It was believed that the period of greatest accumulation of nitrate occurs during the stage of growth immediately preceding the flowering stage. Therefore, all herbicidal applications were timed such that the period of analysis coincided as closely as possible with this stage of growth. Spray applications were made at various dates during the growing season.

Samples for analyses were obtained at 24 hour intervals during four days following treatment and an additional sampling was made two weeks after treatment. Leaves and young stems were included in the samples. Thus, both rapid and slow accumulations of nitrate could be detected. Sampling was done early in the morning to eliminate, as much as possible, the effect of sunlight on the nitrate accumulated during the dark hours.

The samples were taken immediately to the laboratory where extracts were prepared from duplicate samples of the fresh material. The extracts were then analyzed for nitrate content using a colorimetric method which involved the nitration of 3,4–xylenol. Preliminary work indicated that the method gave consistent and reproducible results and that it was much less time consuming than the Kjeldahl method of nitrate determination.

The xylenol method of determining the nitrate in plant materials was first reported by Rauterberg and Benischle in 1949. In this report, several modifications suggested in a personal communication by Dr. G. H. Ellis, United Cooperatives, Inc., Ithaca, New York, were adopted and the modified method is as follows:

1. Reagents
   a. 0.1 percent NaOH.
   b. H_2SO_4 (3:1) 1 volume of water to 3 volumes of concentrated sulfuric acid.
   c. H_2SO_4 (5:1) 1 volume of water to 5 volumes of concentrated sulfuric acid.
   d. 2.0 percent acetone solution of 3,4 xylenol (4 hydroxy 1,2 dimethyl-benzene).
   e. 40 percent phosphotungstic acid.
   f. $Ag(NH_3)_2$ prepare by saturating concentrated, boiling (NH_4OH) with Ag_2SO_4. Concentrate 60 ml. to 30 ml. by boiling and dilute to 100 ml. with distilled water.
   g. CCl_4. Distill over CaO and filter.

2. Procedure
   a. Extract sample in Waring Blendor, 1–10 gm. in 100 ml. water, for 6 minutes. Filter through cotton milk filter

folded like conventional filter paper. Take 20 ml. aliquot, add 2 ml. H_2SO_4 (5:1) and 2 ml. phosphotungstic acid, solution. Centrifuge and take aliquot for nitration.

b. Add 1 ml. of xylenol and 3 volumes of H_2SO_4 (3:1) to aliquot. (5 ml. aliquot and 15 ml. H_2SO_4) Place on shaker for 15 minutes at temperature of 35–55° C.
Caution: The reaction temperature is extremely important. Where total reactant volume is less than 10–15 ml. the tubes may require warming before the 15-minute shaking is completed. If temperature exceeds 55° C. serious loss, due to side reactions, may be encountered.

c. After shaking is completed, dilute with approximately 50 ml. water. Cool and transfer to 125 ml. separatory funnel. Extract with two 15 ml.-portions of CCl_4. Extract the CCl_4 phase with 50 ml. of 0.1 percent NaOH and discard the CCl_4 layer. Filter the aqueous solution and make readings on filtrate in an Evelyn colorimeter with a 440 mμ filter.

A standard curve, for use in comparing the results of the nitrate determinations, was obtained by analyzing solutions containing known quantities of analytical grade potassium nitrate. All of the potassium nitrate values in the tables represent the average of duplicate determinations.

EXPERIMENTAL RESULTS

Based on the data obtained, the weeds sprayed in the experiments were divided into four groups. These are as follows:

1. Weeds which showed no significant differences between chemical treatments or days sampled for analyses are:
   Chenopodium album
   Cirsium arvense
   Prunus virginiana
   Thalictrum dioicum
2. Weeds in which there were differences only between chemical treatments are:
   Eupatorium maculatum
   Impatiens biflora
   Sambucus canadensis
   Solanum Dulcamara
3. Weeds in which there were significant differences between chemical treatments and between days sampled for analyses are:
   Amaranthus retroflexus
   Ambrosia elatior
   Polygonum Convolvulus
   Polygonum Persicaria

4. Weeds which showed significant differences only between the days on which they were sampled for analyses are:
   Poa pratensis
   Spiraea alba

Group One

The nitrate levels of *Chenopodium album* and *Cirsium arvense* were found to be quite high, ranging from 4.1 percent to 4.5 percent potassium nitrate in *Chenopodium album* and 3.4 percent to 4.0 percent in *Cirsium arvense*. The nitrate levels of *Prunus virginiana* and *Thalictrum dioicum* were relatively low being 0.9 percent to 1.0 percent and 0.3 percent to 0.7 percent respectively. Statistical analyses showed that variations between treatments and between days were not large enough to be significant.

Group Two

All chemical treatments except MCPA and 2,4,5–T, significantly increased the nitrate content in *Eupatorium maculatum* at some time during the two week period. There was an immediate increase (24 hours) in nitrate concentration followed by a decline over the two week period. There was no definite pattern of nitrate increase or decrease after the first day, i.e., some treatments, 2,4–D, CIPC and DNBP, caused a gradual increase in nitrate followed by a decrease while MH brought about a decrease in nitrate followed by an increase. MCPA produced significant decreases at the fourth day intervals. On the fourteenth day, only the plants which received the DNBP tratment remained significantly higher in nitrate than the control.

On the first day following treatment of *Impatiens biflora* (Table 1), significant increases were observed for all treatments except that of DNBP. In most cases the nitrate content of sprayed plants remained relatively constant throughout the two-week period. The nitrate level of the control increased constantly, with the result that at the end of the two-week period only the MCPA treated plants remained significantly higher in nitrate than the control.

No significant increases in nitrate content of *Sambucus canadensis* were obtained from any of the herbicide treatments. The 2,4–D treatment caused a highly significant reduction in nitrate content for at least four days following the application. However, the nitrate level in this treatment was similar to that in the majority of other treatments at the end of the two-week period. The nitrate level in the 2,4,5–T sprayed plants remained normal for the first four days but was considerably reduced at the end of two weeks.

Chemical treatments, with the exception of DNBP, caused a significantly lower content of nitrate in *Solanum Dulcamara* (Table 1). On the fourth day following application of the chemicals, the DNBP treated plants contained a significantly greater amount of nitrate than the control. However, analyses at the end of the two-week period showed that the nitrate content of these plants had fallen much below that of the control.

Table 1. Mg of potassium nitrate per gram of dry weight of weeds following application of herbicidal sprays.

Chemical applied	Pounds per acre	Days after treatment											
		Eupatorium maculatum			*Impatiens biflora*			*Sambucus canadensis*			*Solanum Dulcamara*		
		1	4	14	1	4	14	1	4	14	1	4	14
2,4-D	0.25												
	0.50	13.1*	14.9	10.8	12.6*	12.3	12.6**	14.3**	16.1**	24.2**	13.5**	14.6**	11.8**
2,4,5-T	0.25	12.1	8.9**	5.4**	13.6**	14.0	14.9	26.3	25.6	16.8**	11.4**	12.0**	13.5**
MCPA	0.25	8.4	7.1**	13.1	23.0**	23.4**	19.5*	24.2	25.9	24.8*	13.9**	11.8**	12.9**
DNBP	0.50	23.7**	19.3*	23.0**	10.6	12.0	12.9**	22.0	26.3	25.5*	21.9	23.9**	16.0**
CIPC	1.00	14.9**	16.1	11.4	12.6*	12.3	12.3**	21.7*	28.4	25.6	14.1**	16.8**	16.0**
MH	1.00	18.1**	10.6*	15.7	14.0**	14.3*	15.3	25.9	25.3	26.3	13.6**	16.3**	14.4**
Control		8.9	14.9	14.4	9.7	11.6	16.4	25.5	28.8	29.2	22.9	20.5	22.2
L.S.D. between treatments at 5% =			3.8			2.5			3.6			2.3	
L.S.D. between treatments at 1% =			5.2			3.4			4.9			3.2	

Group Three

The nitrate content of this group differed significantly between treatments as well as between days following treatment.

No increases in nitrate content were caused by any of the herbicidal treatments in *Ambrosia elatior*. The nitrate levels were reduced by all treatments but most effectively by 2,4–D; at the end of two weeks the nitrate levels of sprayed plants were well below those of the control.

The results of treating *Amaranthus retroflexus* (Table 2) indicate that on the first day following the application of the herbicides, the nitrate content of all treated plants, except those treated with CIPC, was significantly lower than that of the untreated plants. The nitrate level of all treated lots increased on the second and third days. On the fourth day the nitrate content decreased as compared to the control and after two weeks the nitrate level of all treated plants was considerably below that observed on the first day. In plants treated with DNBP and MH the nitrate content was significantly higher on the fourteenth day than in untreated plants.

Unlike most of the weeds studied, there was no consistent upward or downward trend in the nitrate content of *Polygonum Convolvulus* (Table 2). The nitrate levels varied considerably from day to day but the pattern was not consistent for the different treatments. Plants treated with 2,4–D contained a significantly higher level of nitrate than the control on the first, and fourteenth days, following spraying. Plants treated with 2,4,5–T contained a higher level of nitrate than the untreated plants on the fourth and fourteenth days, while plants which were treated with MCPA contained more nitrate on the fourth day. The increases in nitrate were not significantly higher than in the control plants, except in the plants treated with 2,4,5–T.

The nitrate levels of *Polygonum Persicaria* (Table 2) varied considerably among herbicides on the first day following treatment. All compounds except 2,4–D brought about significant reductions on the first day. The nitrate content generally increased by the fourth day but the increases were not significantly different from the control plants. On the fourteenth day, only the 2,4–D had failed to cause a highly significant decrease in the nitrate content of this weed.

Group Four

Poa pratensis (Table 2) was found to contain very low amounts of nitrate throughout the period in which analyses were made. There were differences in nitrate content between the 24 hour periods in which analyses were made. However, the differences were due to the downward trend in nitrate content which occurred in all *Poa* samples and appeared to be unrelated to herbicidal treatment.

The results obtained from the treatment of *Spiraea alba* were similar to those obtained for *Poa pratensis*.

Table 2. Mg. of potassium nitrate per gram of dry weight of weeds following application of herbicidal sprays.

Chemical applied	Pounds per acre	Days after treatment														
		Ambrosia elatior			*Amaranthus retroflexus*			*Polygonum Convolvulus*			*Polygonum Persicaria*			*Poa pratensis*		
		1	4	14	1	4	14	1	4	14	1	4	14	1	4	14
2,4-D	0.25	20.3**	21.6**	13.9**	35.4**	37.6**	19.2**	19.4*	16.6	17.1**	32.3	38.6	37.1	5.6	3.4	3.4
2,4,5-T	0.25	27.1	25.6**	12.3**	36.0**	37.6**	23.0	17.6	17.1*	17.1**	29.4*	34.2*	30.9**	5.3	3.1	3.0
MCPA	0.25	21.0**	23.6**	13.5**	37.1*	37.6**	18.1**	19.1	20.2**	16.1	26.8**	36.6	25.8**	4.5	2.9	2.8
DNBP	0.50	27.0	26.7**	10.4**	31.3**	37.6**	28.4**	9.1**	13.1	12.8	24.4**	34.7	32.3**	4.5	3.3	2.9
CIPC	1.00	23.9**	25.6**	11.1**	39.8	41.6	25.9	18.9	15.1	16.1	28.0**	37.6	28.2**	4.5	2.6	2.9
MH	1.00	25.0**	25.6**	13.4**	35.4**	39.8**	27.1*	14.6*	12.9	12.8	26.1**	37.9	20.0**	2.6	2.7	1.6
Control		28.6	32.2	18.0	39.8	43.4	24.5	17.1	14.9	14.2	34.2	38.6	38.0	4.8	3.9	2.6
L.S.D. between treatments at 5% =		2.3			2.6			2.1			4.1			Difference not significant		
L.S.D. between treatments at 1% =		3.2			3.5			2.8			5.5					

DISCUSSION

A number of research workers have shown that sub-lethal dosages of 2,4–D, and other herbicides, have remarkable effects on the metabolism of the treated plants (1, 3, 6, 9, 15). Not all species of plants are affected in the same manner nor to the same degree. This is evident from the varying degrees of tolerance exhibited by different species of plants to a particular chemical. The metabolic abnormalities, brought about by herbicidal treatment, may cause plants to accumulate nitrate in the same manner as is done when plants are placed under adverse growing conditions, such as drought.

Nitrate accumulation following treatment with 2,4–D has been reported in the case of *Chenopodium album* (18). This effect was not found in this study and may be accounted for by differences in environmental conditions under which the work was done. Bradley et al. (2) showed that the type of soil determined to a great extent the amount of nitrate in plants, even when the nitrate level of the soil was high. Wide differences in soil types and soil moisture conditions may give rise to entirely conflicting results.

Herbicidal treatments used in this study did not affect the nitrate content of the following species: *Chenopodium album, Cirsium arvense, Prunus virginiana* and *Thalictrum dioicum.*

The herbicidal treatments on two species, *Eupatorium maculatum* and *Impatiens biflora,* caused rapid increases in nitrate content. In the majority of weeds treated there was either a reduction or no change in nitrate content during the period in which analyses were made.

Some weeds, for example: *Ambrosia elatior, Amaranthus retroflexus* and *Polygonum Persicaria,* were observed to accumulate nitrate on the second, third and fourth days following herbicidal treatment. In these weeds there was some reduction in nitrate content from the fourth to the fourteenth day following treatment. These increases and decreases in nitrate level occurred in both the treated plants and the controls, indicating that factors other than the herbicidal treatments contributed to the changes in the nitrate levels. Variations of temperature, light, moisture and the progress of the plants from one stage of growth to another could account for the changes in the nitrate level of both treated plants and the control.

In no case did any particular herbicidal treatment result in consistently higher or lower nitrate levels in all species. For example, it was observed that the 2,4–D treatment caused lower nitrate levels than the other treatments when applied to *Ambrosia elatior, Sambucus canadensis* and *Polygonum Persicaria.* The reverse was true in the case of *Polygonum Convolvulus.*

Ten of the 14 weeds were found to contain nitrate levels in excess of the one and one-half percent considered by Bradley et al. (2) to be the maximum concentration of nitrate in plants which livestock could safely consume. These ten weeds were: *Amaranthus retroflexus, Ambrosia elatior, Chenopodium album, Cirsium arvense, Eupatorium maculatum, Impatiens biflora, Polygonum Convolvulus, Polygonum Persicaria, Sambucus canadensis* and *Solanum Dulca-*

mara. In only two weeds could the toxic level of nitrate be attributed entirely to the effects of herbicidal treatment. The application of 2,4–D, DNBP, CIPC and MH to *Eupatorium maculatum* resulted in a rapid accumulation of nitrate to the extent that the plant could, if consumed by livestock in sufficient quantities, cause nitrate poisoning. The application of MCPA, CIPC and MH to *Impatiens biflora* resulted in similar increases in nitrate concentration.

Livestock poisoning by *Solanum Dulcamara* and *Prunus virginiana* frequently has been reported. The 2,4–D and 2,4,5–T treatments, which often have been employed in eradicating these two species, did not result in increased levels of nitrate in these plants.

The data indicate that large day to day variations in nitrate content were common and were often of greater significance than the variations due to the chemical treatments.

SUMMARY AND CONCLUSIONS

1. Fourteen species of weedy plants were treated with six different herbicides and the effect of the treatments on the nitrate content was determined.

2. The herbicides were applied at sub-lethal dosages and analyses of the nitrate content were made on the first, second, third, fourth and fourteenth days following the application.

3. The nitrate content of the weeds was determined by a comparison with standard solutions of potassium nitrate using a method involving the nitration of 3,4–xylenol.

4. The nitrate level of four of the treated weeds were unaffected by the herbicidal application. These weeds were: *Chenopodium album, Cirsium arvense, Prunus virginiana* and *Thalictrum dioicum*.

5. Herbicidal treatment of five of the weeds resulted in significant increases in nitrate content. These weeds and treatments were:

   a. The DNBP treatment of *Amaranthus retroflexus*
   b. The 2,4–D, DNBP, CIPC and MH treatments of *Eupatorium maculatum*
   c. All herbicides on *Impatiens biflora*
   d. The 2,4–D, 2,4,5–T and MCPA treatments of *Polygonum Convolvulus*
   e. The DNBP treatment of *Solanum Dulcamara*.

6. Herbicidal treatments of *Polygonum Persicaria* caused significant reductions in nitrate content.

7. Ten of the 14 weeds studied contained nitrate in sufficient quantities to cause nitrate poisoning of livestock if consumed in considerable quantities even though no sprays had been applied.

8. In only two of the weeds could the accumulation of toxic concentrations of nitrate be attributed solely to the effect of herbicidal treatment. These two weeds were *Eupatorium maculatum* and *Impatiens biflora*.

9. No herbicide appeared to have the same affect on all of the weeds tested.

10. Of the two weeds, *Chenopodium album* and *Amaranthus retroflexus,* previously reported to accumulate nitrate following treatment with 2,4–D (8), it was found that *Chenopodium* was not affected by any of the treatments and *Amaranthus* accumulated nitrate only as a result of the DNBP treatment.

LITERATURE CITED

1. BEEVERS, H. 2,4–Dinitrophenol and plant respiration. Amer. Jour. Bot. 40:91–96. 1953.
2. BRADLEY, W. B., EPPSON, H. F., and BEATH, O. A. Livestock poisoning by oat hay and other plants containing nitrates. Wyoming Agric. Expt. Sta. Bull. 241, pp. 1–20. 1940.
3. DAVIDSON, O. W., DOUGHTY, J. L., and BOLTON, J. L. Nitrate poisoning in livestock. Canadian Jour. Comp. Med. 5:303. 1941.
4. FERTIG, S. N. Livestock poisoning from herbicide treated vegetation. Proc. Northeast. Weed Control Conf., pp. 13–19. 1952.
5. ———. Herbicidal poisoning of livestock. Proc. Northeast. Weed Control Conf., pp. 44–47. 1953.
6. GRIGSBY, B. H. Some effects of 2,4–D on ragweed and certain woody plants. Michigan State Coll. Agric. Expt. Sta. Quart. Bull. 28:304–310. 1946.
7. ——— and BALL, C. D. Some effects of herbicidal sprays on the hydrocyanic acid content of leaves of wild black cherry *(Prunus serotina Ehrhart).* Proc. Northeast. Weed Control Conf., pp. 327–330. 1953.
8. KLINGMAN, G. C., and AHLGREN, G. H. Effects of 2,4–D on dry weight, reducing sugars, total sugars, polysaccharides, nitrogen and allyl sulfide in wild garlic. Bot. Gaz. 113:119–134. 1951.
9. LYNN, G. E., and BARRONS, K. C. The hydrocyanic acid (HCN) content of wild cherry leaves sprayed with a brush killer containing low volatile esters of 2,4–D and 2,4,5–T. Proc. Northeast. Weed Control Conf., pp. 331–333. 1952.
10. NEWSOM, I. E., and STOUT, E. W. Oat hay poisoning. Jour. Amer. Vet. Med. Assoc. N. S. 43:66–75. 1937.
11. OLSON, O. E., and WHITEHEAD, E. Nitrate content of some South Dakota plants. Proc. S. Dakota Acad. Sci. 20:95–101. 1940.
12. ROGERS, C. F., and BOYD, W. L. Sudan grass and other cyanophoric plants as animal intoxicants. Jour. Amer. Vet. Med. Assoc. 88:489–499. 1936.
13. SAVAGE, A. U. Nitrate poisoning from sugar beet tops. Canadian Jour. Comp. Med. 13:9–10. 1949.
14. SMITH, F. G., HAMNER, C. L., and CARLSON, R. F. Changes in food reserves and respiratory capacity of bindweed tissues accompanying herbicidal action of 2,4–dichlorophenoxyacetic acid. Plant Physiol. 22:58–65. 1947.
15. STAHLER, L. M., and WHITEHEAD, E. I. The effect of 2,4–D on potassium nitrate levels in leaves of sugar beets. Science 112:749–751. 1950.
16. VETERINARY DEPARTMENT. Cattle poisoning by nitrate of potash. Kansas Agric. Expt. Sta. Bull. 49:3–11. 1895.
17. WHITEHEAD, E. I., and OLSON, O. F. A study of some factors affecting the nitrate content of plants. Proc. S. Dakota Acad. Sci. 21:67–72. 1941.
18. WILLARD, C. J. Indirect effects of herbicides. Proc. North Cent. Weed Control Conf., pp. 110–112. 1950.

Effects of Amino Triazole Salts and Derivatives on Cotton Defoliation, Growth Inhibition and Respiration

C. S. Miller and Wayne C. Hall[1]

The compound 3–amino–1, 2,4–triazole (ATA) is water soluble, heterocyclic and will react with most acids and bases to form salts (1). Several workers (2, 6, 9) have reported that ATA is a promising herbicide for the control of a number of weed species. ATA was first noted to have defoliating and regrowth-inhibiting properties on cotton in tests conducted by workers of the Texas Agricultural Experiment Station in 1952 (3). The compound was found to increase the effectiveness of many commercial defoliants while adding the property of regrowth inhibition (10). During 1954 and 1955, a number of tests were conducted with various salts and derivatives of ATA in the hope that they would be more effective at lower rates as cotton defoliants and regrowth inhibitors. The present paper compares the performance of ATA with eight of its salts or derivatives which were found to be the most successful in defoliating cotton and controlling regrowth after preliminary screening in the greenhouse.

Materials and Methods

ATA, the acetate, hydrochloride, lactate, nitrate, pentachlorophenol, phosphate, and sodium salts of ATA, and 3–(salicylideneamino)–1,2,4–triazole (SATA) were used in the studies. Aqueous solutions of ATA and its formulations were prepared on the amino triazole equivalent basis except where noted in Table 1.

Cotton plants of the Deltapine variety used in the study were either grown in fertile soil in three-gallon jars in the greenhouse or in the field according to the cultural practices of the area. The compounds were applied after approximately 50 per cent or more of the bolls had opened. Eight or more cotton plants were used for each treatment in the greenhouse studies. In the field applications, two-row plots approximately 100 feet long with a buffer row between plots were employed. The experimental design for the field tests was a randomized block with three replications. Leaves were counted prior to and either 8 or 10 days following application to determine the percentage defoliation. Defoliation percentages in the field were based on ten randomly selected plants per plot or 30 plants per treatment. The regrowth produced in 3 weeks by eight or more plants per treatment in the greenhouse and by ten plants per plot in the field were collected, combined for each treatment, and weighed. In the greenhouse experiments, the aqueous solutions were applied with a carbon dioxide-pressured hand sprayer until the foliage was thoroughly wetted. Compounds were applied to field plants in 32 gallons of water per acre by means of a high clearance, self-propelled sprayer.

[1]Research Fellow and Professor, Dept. of Plant Physiology and Pathology, Texas A. and M. College System, College Station, Texas.

Prior to the field applications the relative growth inhibiting properties of ATA and six of its salts were assayed by the *Avena* coleoptile section straight growth test. It was hoped that this would serve as a quick method to determine the regrowth inhibiting potential of the compounds in the field. *Avena* seedlings were grown in the dark in moist vermiculite in stainless steel trays at 25° C. At 82 to 84 hours of age the seedlings were selected for uniformity, the apical 2 to 3 mm. of the tip was removed, and 5 mm. sections were cut with a double bladed tool. The sections were pooled and a random selection of 20 was placed in a petri dish containing 20 ml. of the test solution. ATA or its salts at concentrations of 100 and 500 ppm were added to a basal solution containing citric acid monohydrate, dibasic potassium phosphate buffer (pH 5.0) and 3 per cent sucrose. The assay was repeated three times using different lots of coleoptiles. The sections were allowed to grow in the dark at 25–26° C. for a period of 16 hours, after which their lengths were measured under a wide-field microscope fitted with an eyepiece micrometer. Growth of *Avena* sections has been found to be linear with time for 18 hours (8). The results are expressed as the mean per cent elongation in 16 hours.

The ability to stimulate respiration appears to be an important attribute of a successful cotton defoliant (5, 7). Therefore, the effects of ATA and its derivatives on oxygen uptake of treated and untreated *Avena* coleoptile sections and cotton leaf discs were determined with a Warburg-type micro-respirometer according to methods previously described (5, 11). Two-tenths ml. of 20 per cent KOH was used in the center well and an oscillation rate of 180 strokes per minute was employed. The flasks were allowed 15 minutes to reach equilibrium with the temperature of the bath before closing the manometer stopcocks. All measurements were made at 25° C.

At the time of cutting the *Avena* sections for the straight growth measurements, comparable samples were cut for respiratory measurements. Twenty sections were placed in duplicate flasks, each containing 2 ml. of the test solution.

Ten mature cotton plants per treatment were sprayed with a hand sprayer using 4,000 ppm concentrations of ATA and the different salts. At 4 and 26 hours after application, leaf discs were cut with a No. 6 cork borer, with no more than three discs being taken from a single leaf. Twenty discs were placed in each duplicate flask.

Following oxygen uptake measurements, the sections and discs were oven dried at 65 to 75° C. to constant weight. The results were expressed as microliters of oxygen consumption per mg. dry weight per hour (Q_{O2}).

RESULTS AND DISCUSSION

Greenhouse and field tests. Representative results obtained in the greenhouse in 1954 are summarized in Table 1. The plants were active at the time of application and gave better defoliation at the lower rates than is usually obtained. Comparison on an ATA equiva-

Table 1. Effects of amino triazole, salts of amino triazole and derivatives on defoliation and regrowth of greenhouse grown cotton in 1954.

Chemical	Concentration in ppm.		Defoliation in 10 days pct.	Regrowth after 3 weeks gms/plant
	Total chemical basis	ATA equivalent basis		
ATA	1,500	1,500	54.3	12.3
ATA	5,000	5,000	85.7	3.8
Acetate salt of ATA	1,500	873	70.0	9.0
Acetate salt of ATA	5,000	2,910	86.4	5.0
Hydrochloride salt of ATA	1,500	1,045	67.1	4.3
Hydrochloride salt of ATA	5,000	3,485	68.8	2.4
Nitrate salt of ATA	1,500	856	56.6	6.2
Nitrate salt of ATA	5,000	2,855	88.6	3.1
Phosphate salt of ATA	1,500	693	73.8	4.9
Phosphate salt of ATA	5,000	2,310	88.9	4.8
Sodium salt of ATA	1,500	1,188	75.9	2.3
Sodium salt of ATA	5,000	3,960	84.0	1.3
Pentachlorophenol salt of ATA	1,500	570	66.0	7.0
Pentachlorophenol salt of ATA	5,000	1,900	63.0	5.0
Lactate salt of ATA	1,500	870	65.8	4.6
Lactate salt of ATA	5,000	2,900	87.0	4.8
3-(Salicylideneamino)-1,2,4-triazole	1,500	1,125	77.3	12.5
3-(Salicylideneamino)-1,2,4-triazole	5,000	3,750	80.0	2.9

lent basis indicated increased defoliating activity of the salts and SATA over ATA. On the ATA equivalent basis the salts and SATA were also equal to or better in controlling regrowth than ATA.

At low concentrations of compounds, to permit further study of possible differences in regrowth-retarding ability, all treatments gave poor defoliation in the greenhouse during 1955 (Table 2). The

Table 2. Effects of amino triazole, salts of amino triazole and derivatives on defoliation and regrowth of greenhouse grown cotton in 1955.

Chemical	Concentration in ppm[1]	Defoliation in 10 days pct.	Regrowth after 3 weeks gms/plant
ATA	1,500	32.1	12.5
Acetate salt of ATA	1,500	34.0	19.0
Hydrochloride salt of ATA	1,500	33.8	9.0
Phosphate salt of ATA	1,500	35.5	14.0
Lactate salt of ATA	1,500	30.9	8.0
Sodium salt of ATA	1,500	24.8	4.5
Nitrate salt of ATA	1,500	22.0	12.0

[1]ATA equivalent basis.

plants were slightly inactive at the time the chemicals were applied. The difference in defoliation obtained with 1500 ppm ATA in 1954 and 1955 clearly demonstrates the variability encountered in cotton defoliation work, even under greenhouse conditions, and emphasizes the importance of plant activity and the proper timing of defoliant application. Based on the 1955 greenhouse results, the hydrochloride, lactate, sodium, and nitrate salts were superior to ATA in retarding regrowth. The sodium salt was the most effective, and the acetate salt the least effective in inhibition of regrowth. Figure 1 compares differences among the salts in controlling regrowth 3 weeks after appliaction to plants in a 1956 greenhouse test.

Field tests conducted during 1954 and 1955 in the Brazos River Valley and during 1955 in the Lower Rio Grande Valley showed no consistent advantages of the salts over ATA as a cotton defoliant (Tables 3 and 4). Statistical analyses of the data confirmed that differences in defoliation were not significant in any of the field tests for either the 1 or 2 pound rates. Poorer defoliation in the Lower Rio Grande Valley can be partly attributed to an inadequate late season insect control program that permitted shedding of all upper bolls and which caused extremely vegetative plants. In all field tests the 1 pound rate of the nitrate salt gave better defoliation than higher rates of this salt. In general, regrowth was reduced more by the salts than with the same rate of ATA, the differences being statistically significant. Regrowth in the 1955 test in the Brazos River Valley was destroyed by leaf worms prior to its collection.

Although some of the greenhouse results indicated that the salt formulations were more active than ATA as defoliants, this was not confirmed in the field tests presented (Tables 3 and 4) or by the

Table 3. Effects of amino triazole, salts of amino triazole and derivatives on the defoliation and regrowth of cotton grown in the Brazos River Valley without (1954) and with (1955) irrigation.

Chemical	Application lb/A[1]	1954		1955
		Defoliation in 10 days pct.	Regrowth in 3 weeks gms/plot	Defoliation in 8 days pct.
ATA	1.0	93.6	20.0	85.1
ATA	1.5	92.1	18.4	—
ATA	2.0	91.8	8.6	92.8
Acetate salt of ATA	0.75	91.6	22.0	—
Acetate salt of ATA	1.0	—	—	87.1
Acetate salt of ATA	2.0	—	—	86.3
Hydrochloride salt of ATA	1.0	—	—	89.2
Hydrochloride salt of ATA	2.0	—	—	90.8
Lactate salt of ATA	1.0	—	—	90.6
Lactate salt of ATA	2.0	—	—	91.2
Nitrate salt of ATA	0.75	97.7	9.0	—
Nitrate salt of ATA	1.0	—	—	87.7
Nitrate salt of ATA	2.0	—	—	84.6
Phosphate salt of ATA	0.67	89.7	16.0	—
Phosphate salt of ATA	1.0	—	—	75.8
Phosphate salt of ATA	2.0	—	—	89.0
Pentachlorophenol salt of ATA	0.57	94.8	34.0	—
Sodium salt of ATA	1.0	—	—	84.1
Sodium salt of ATA	2.0	—	—	94.5
3-(Salicylideneamino)-1,2,4-triazole	1.13	91.7	18.0	—

[1]Applications expressed on the ATA equivalent basis.

results of other field applications. It is apparent that the percentage defoliation obtained in the field depends primarily upon the actual amount of ATA applied rather than the formulation of ATA used. Figure 2 shows excellent defoliation and regrowth control in irrigated cotton from an aerial application of a combination of magnesium chlorate and ATA.

Avena section experiments. Percentage elongation and oxygen uptake of *Avena* sections floated on buffered solutions are shown in

Table 4. The influence of amino triazole and its salts on defoliation and regrowth of cotton grown under irrigation in the Rio Grande Valley in 1955.

Chemical	Application lb/A[1]	Defoliation in 8 days pct.	Regrowth in 3 weeks gms/plant
ATA	1.0	61.9	26.2
ATA	2.0	65.0	32.5
Nitrate salt of ATA	1.0	73.8	13.9
Nitrate salt of ATA	2.0	64.0	20.6
Phosphate salt of ATA	1.0	56.3	12.5
Phosphate salt of ATA	2.0	63.8	13.3
Lactate salt of ATA	1.0	51.9	25.4
Lactate salt of ATA	2.0	53.3	19.5
Hydrochloride salt of ATA	1.0	59.5	22.5
Hydrochloride salt of ATA	2.0	70.5	23.1
Sodium salt of ATA	1.0	71.8	31.2
Sodium salt of ATA	2.0	54.4	13.4

[1]ATA equivalent basis.

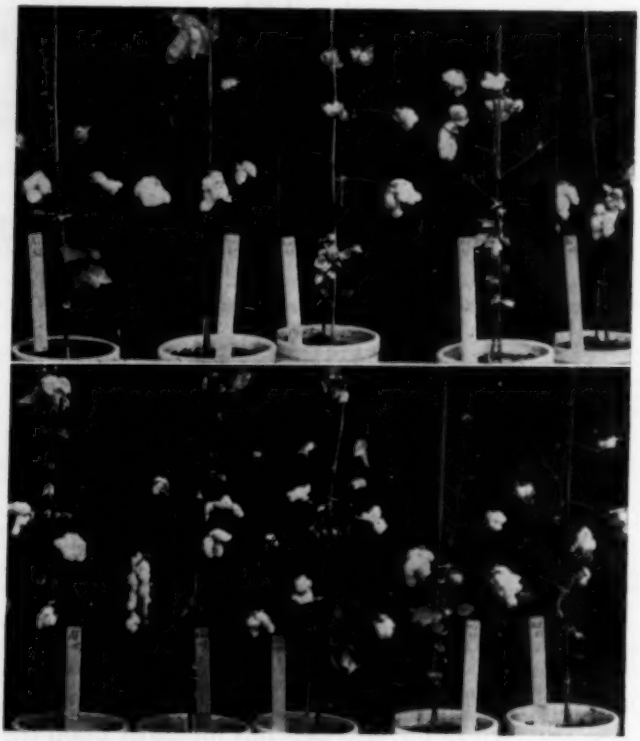


Figure 1. Regrowth inhibition by ATA and its salts three weeks after application to greenhouse-grown cotton. Bottom, left to right—1,500 ppm ATA, 5,000 ppm nitrate salt of ATA, 1,500 ppm nitrate salt of ATA, 1,500 ppm hydrochloride salt of ATA, and 5,000 ppm hydrochloride salt of ATA. Top, left to right—5,000 ppm ATA, 1,500 ppm phosphate salt of ATA, 5,000 ppm phosphate salt of ATA, 1,500 ppm sodium salt of ATA, and 5,000 ppm sodium salt of ATA.

Figure 2. Bottom—defoliation of irrigated cotton with a magnesium chlorate-ATA combination. Top—same field showing excellent regrowth control 5½ weeks after application.

Table 5. The acetate salt of ATA was the most effective in inhibiting growth of *Avena* sections, yet gave poor control of cotton regrowth in the field compared to ATA. It was thought that poor absorption or translocation of the acetate salt by intact plants caused the reduction in inhibition. A wetting agent added to the acetate salt when applied in the field, however, did not increase defoliation or inhibition of regrowth.

ATA, at the low concentrations used, exhibited very little influence on elongation of the sections when compared to the control. A previous study (4) without added sucrose in the buffer solution showed that growth of *Avena* sections decreased as ATA concentration increased up to 8,400 mg/l.

The hydrochloride, lactate, nitrate, and sodium salts caused varying degrees of inhibition. The unexpected stimulation in growth of sections at the higher concentration of the phosphate salt was consistently reproducible and merits further study. Since all solutions contained the phosphate buffer, it is apparent that growth stimulation was not due solely to inorganic phosphate. When applied to

Table 5. Influence of amino triazole and its salts on growth and oxygen uptake of dark-grown *Avena* coleoptile sections.

Chemical	Concentration ppm	Percentage elongation in 16 hrs.	Q_{O_2} µls. O_2/mg/hr
Control (basal solution only)	—	38.9	3.17
ATA	100	38.4	4.52
ATA	500	37.8	4.74
Acetate salt of ATA	100	26.6	5.98
Acetate salt of ATA	500	0.0	4.48
Hydrochloride salt of ATA	100	35.9	5.54
Hydrochloride salt of ATA	500	27.7	5.36
Lactate salt of ATA	100	31.6	4.76
Lactate salt of ATA	500	29.3	5.81
Nitrate salt of ATA	100	32.8	5.55
Nitrate salt of ATA	500	15.2	5.82
Phosphate salt of ATA	100	38.8	5.52
Phosphate salt of ATA	500	50.7	5.55
Sodium salt of ATA	100	30.8	4.55
Sodium salt of ATA	500	25.7	4.85

intact cotton plants, the phosphate salt inhibited secondary growth. Thus it appears that the *Avena* straight growth test is not highly reliable as a screening method for potential regrowth inhibitors for cotton.

The average oxygen uptake values of *Avena* sections floated on the various salts are given in Table 5. ATA and the salts stimulated oxygen uptake of the sections over the controls. Respiration increased with an increase in concentration from 100 to 500 ppm with the exception of the acetate salt.

Oxygen use of cotton leaf discs. Average Q_{O_2} values at 4 and 26 hours after treatment are found in Table 6. The sodium and lactate salts of ATA caused the greatest stimulation and the hydrochloride salt the greatest reduction in respiration shortly after application. At the end of 26 hours all oxygen uptake values were approximately the same as the control. It was found in an earlier study (4) that 84, 840, and 8,400 mg/l of ATA increased the oxygen uptake of cotton leaf discs from 20 to 60 per cent over controls within 3 hours following treatment. Between 24 and 48 hours after ATA application, oxygen uptake was inhibited by the 2 higher levels of ATA and had dropped below that of the controls at the 72 hour measurements. At the 84 mg/l level the respiratory rate increased progres-

Table 6. Effect of amino triazole and its salts on oxygen uptake of leaf discs from field-grown cotton.

Chemical	Concentration ppm	Q_{O_2}–µls. O_2/mg/hr	
		After 4 hrs.	After 26 hrs.
Control (untreated)	—	1.54	1.36
ATA	4,000	1.57	1.42
Acetate salt of ATA	4,000	1.66	1.41
Hydrochloride salt of ATA	4,000	1.25	1.36
Lactate salt of ATA	4,000	2.20	1.37
Nitrate salt of ATA	4,000	1.69	1.37
Phosphate salt of ATA	4,000	1.48	1.37
Sodium salt of ATA	4,000	2.21	1.43

sively up to 72 hours after treatment. Based on the results of both the present and previous (4) studies, it appears that the initial effect of ATA is to stimulate respiration in cotton leaf blade tissue followed by inhibition with time at levels above 840 mg/l. The degree and rate of inhibition apparently depend on the concentration of ATA and the time after application.

SUMMARY

1. The defoliating and regrowth-inhibiting properties of amino triazole and eight of its salts or derivatives were compared in greenhouse and field tests conducted during 1954, 1955 and 1956. The phosphate salt gave the highest defoliation, and regrowth was inhibited most by the sodium salt in the greenhouse tests. Significant differences in defoliation were not demonstrated between amino triazole and salts of amino triazole in the field tests.

2. Elongation of *Avena* sections was inhibited significantly by the acetate, hydrochloride, lactate, nitrate, and sodium salts of ATA, while the phosphate salt stimulated *Avena* section growth. Subsequent testing of the compounds on field-grown cotton for their ability to inhibit regrowth showed that the straight growth *Avena* section assay method is not adequate for screening potential cotton regrowth inhibitors.

3. Amino triazole and salts of amino triazole generally caused an initial stimulation of respiration of *Avena* sections and cotton leaf discs. After 26 hours the oxygen uptake of treated leaf discs was approximately the same as controls.

ACKNOWLEDGMENTS

The authors are indebted to the American Chemical Paint Company, Ambler, Pennsylvania, for supplying the ATA and salts used in the work. Thanks are also due to Anderson, Clayton and Company, Houston, Texas, for providing a fellowship for the senior author.

LITERATURE CITED

1. AMERICAN CHEMICAL PAINT COMPANY. Technical service data sheet H–52 on Amizol. 1954.
2. BURT, E. O. Control of nut grass with herbicides and tillage. Proc. Southern Weed Conf. pp. 405–408. 1955.
3. HALL, W. C., TRUCHELUT, G. B., and LANE, H. C. Chemical defoliation and regrowth inhibition in cotton. Texas Agr. Exp. Sta. Bul. 759. 1953.
4. HALL, W. C., JOHNSON, S. P., and LEINWEBER, C. L. Amino triazole—a new abscission chemical and growth inhibitor. Texas Agr. Sta. Bul. 789. 1954.
5. HALL, W. C., and LANE, H. C. Compositional and physiological changes associated with the chemical defoliation of cotton. Plant Physiol. 27:754–768. 1952.
6. LEE, O. C. Response of Canada thistle to 3-amino-1,2,4-triazole. Proc. North Central Weed Conf. pp. 12. 1954.
7. LEINWEBER, C. L., and HALL, W. C. Respiration in the cotton leaf abscission zone as affected by age and defoliants. Proc. Tenth Ann. Cotton Defol. Conf. pp. 54. 1955.

8. McRae, D. H., and Bonner, J. Chemical structure and anti-auxin activity. Physiol. Plant. 6:485–510. 1953.
9. Raleigh, S. M. Quackgrass Control. Proc. Northeastern Weed Conf. pp. 277–278. 1955.
10. Texas Agri. Exp. Sta. Progress Report 1763. Cotton defoliation and desiccation tests in Texas. 1954.
11. Umbreit, W. W., Burris, R. H., and Stauffer, J. R. Manometric techniques and tissue metabolism. Univ. of Wisc. Press. 1951.

Chemical Weeding and Thinning when Using Pelletized Vegetable Seeds[1]

V. L. Guzman[2]

When a small seed is covered with an inert material which makes it relatively large and round, it is called a pelletized seed. The main advantage in using pelletized vegetable seeds is that they can be planted at regulated distances from each other. This decreases the number of doubles and makes thinning easier and cheaper. If perfect seed germination and seedling survival were possible, pelletized seed could be planted at the distance required for each crop and thinning could be eliminated. This is impossible in practice, however, and more seeds than are required for final stand must be planted. As a result, thinning is necessary. This is usually done by hoeing out the extra plants. Weeds in the rows are removed at the same time.

Hoeing tends to nullify the effect of pre-emergence chemical weed control by disturbing the soil which results in the emergence of new weed seedlings in the row. If an appropriate herbicide could be employed for thinning as schematically indicated in Figure 1, the

Figure 1. Theoretical pattern of chemical thinning. The plants in the dark sprayed areas would have been killed, whereas the plants in the narrow unsprayed areas would have been the ones remaining to maturity.

[1]Presented at the National Meeting of the Weed Society of America, New York City, January 6, 1956. Florida Agri. Exp. Sta. Jour. Series, No. 569.

[2]Everglades Experiment Station, Belle Glade, Florida.

soil would not be disturbed and some herbicidal effect could be added to the pre-emergence treatment. This should result in better and more lasting control of weeds than is the case with mechanical thinning. Furthermore, by using a tractor-mounted and operated spray rig more efficient thinning might be obtained. A series of experiments has been conducted to test the validity of this hypothesis.

METHODS

Pelletized cabbage, lettuce and pepper seeds were planted in muck soil 2.5 to 4.5 inches apart and between 1/8 and 1/4 inch deep using a Cole planter with a modified asparagus seed plate (Figure 2). It was possible to plant each seed at any desired distance by plugging one or two alternate holes in the plate and changing the gear ratios of the planter.

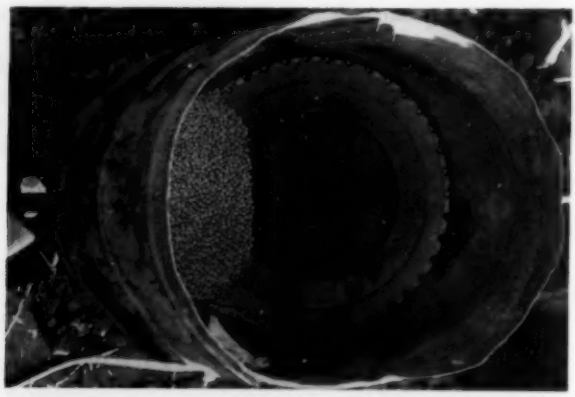


Figure 2. Standard Cole planter with asparagus plate. Note that only one seed is picked up in each hole of the planter.

Pre-emergence weed control treatments consisted of 10 pounds of isopropyl N–(3–chlorophenyl) carbamate (CIPC) for lettuce, 4 to 8 pounds of 2–chloroallyldiethyldithiocarbamate (CDEC) for cabbage and 10 pounds of octachlorocyclohexenone (Oktone) for peppers. Chemicals are expressed in pounds per acre of active ingredient. Chemical thinning was done 2 to 3 weeks after emergence by using an herbicide (for residual weed control) mixed with oil, mineral spirits or diesel oil (for contact kill, thus for thinning). Materials were applied either with a knapsack sprayer or by means of a power sprayer operated from a tractor. In the former case, flow was controlled with a mechanical valve manipulated by hand. With the power sprayer, flow was controlled as above in one case, and by means of a solenoid valve in another. Current was supplied for the solenoid from a 6-volt battery, and was manipulated by hand through a door switch. The ground speed of the tractor was 1 mph in the pepper experiment and 0.64 mph in the cabbage factorial

experiment. In the latter case the thinning nozzles were placed 3 inches above the ground and each equipped with 10-pound check valves. Spraying pressures varied from 10 to 15 psi.

In the first three experiments crops were harvested 5 to 6 weeks after planting. In the later three experiments two rows per treatment were planted at half the row distance required for the crop; one row was harvested 5 to 6 weeks after planting and the other row left to grow to maturity, at which time it was harvested.

In order to ascertain the effect of drift of the thinning material on the crop plants, wind velocity was taken 2 inches above the soil surface by means of a Keuffel & Esser anemometer.

Plots were single or double rows, 30 feet long and replicated six times, except in the factorial experiment which was replicated three times. In the 3 x 3 x 3 factorial experiment seeding distances were indicated by: S_0–2.5 inches, S_1–3.5 inches and S_2–4.5 inches. Rates of pre-emergence treatment were: C_0–none, C_1–4 pounds and C_2–8 pounds of CDEC. The rates of thinning material (Oktone) was indicated by: O_0–none, O_1–2 pounds and O_2–4 pounds. Where no chemical was used (O_0), thinning was done by hand hoeing. Where thinning was done by Oktone in diesel oil (O_1 and O_2) the spray assembly and solenoid valves were mounted and operated from a tractor.

RESULTS

Although the data presented in Table 1 show no significant differences in the stand of lettuce and cabbage, plants thinned chemically were heavier than those thinned with a hoe. In addition, better weed control was obtained with chemical than with mechanical thinning. Chemical thinning was done when the wind velocity was nil.

Table 1. Effects of thinning by hoeing and thinning with chemicals applied with a knapsack sprayer on the stand and weight of 20 lettuce and cabbage plants and weed control.

Crop	Method of thinning	Plants per 30 feet	Plant weight gms.	Weed control index[1]
Lettuce	Hoed	30	151	5
	CIPC—4 lb/A	26	208*	9
Cabbage	Hoed	34	161	5
	Oktone—4 lb/A	32	211*	7

*Significantly different from hoed at 5% level.
[1]0, no control; 10, excellent control.

The results of the second experiment are shown in Table 2. Chemical thinning was done with a knapsack sprayer when the wind was blowing at 3 mph. Better weed control was obtained by chemical thinning than by hoeing and, in general, stand and weight of lettuce and cabbage plants were not altered by the treatments. There was an exception, however, in the case of the cabbage plants treated with CDEC, where the stand was significantly better. This

Table 2. Stand and weight of 20 lettuce and cabbage plants and degree of weed control obtained by mechanical thinning in comparison to chemical thinning using a knapsack sprayer on seedlings spaced 4 inches apart.

Crop	Method of thinning	Plants per 30 feet	Plant weight gms.	Weed control index[1]
Lettuce	Hoed	28	204	6
	CIPC—4 lb/A	25	205	9
	CDEC—4 lb/A	25	179	9
Cabbage	Hoed	25	268	6
	Oktone—4 lb/A	25	233	9
	CDEC—4 lb/A	29*	255	9

*Significantly different from hoed cabbage at 5% level.
[1]0, no control; 10, excellent control.

nearly perfect stand (30 plants per 30-foot row would be perfect) is not attributed to chemical thinning but to an increase in the operator's efficiency which was gained by experience. Chemical thinning started early in the morning with the Oktone treatment and by the time the CDEC plots were thinned the operator had gained sufficient co-ordination to do an excellent job.

Table 3. Effect of methods of thinning on stand, weight, number of doubles of pepper plants and weed control.

Method of thinning	Average stand in 30 feet		Average doubles in 30 ft.	Weight of 20 plants grams	Weed control[1]
	Before thinning	After thinning			
Hoed	59	29	0.6	370	5
Oktone—4 lb/A by hand sprayer	58	27	0.6	320	6
Oktone—4 lb/A by power sprayer	62	21*	0.8	287**	6

[1]0, no control; 10, excellent control.
*Significantly different from hoed at 5% level.
**Significantly different from hoed at 1% level.

In the data presented in Table 3, reduction in stand and weight of pepper plants was associated with thinning when using a tractor at 1 mph speed. This can be attributed to (1) effect of wind drift on the crop (wind with gusts up to 4 mph), (2) the relatively fast speed of the tractor, and (3) the slow action of the hand operated mechanical valves for the spray jets. It was visible immediately after chemical thinning that plants not intended to be sprayed were damaged by drift or by light contact with the chemical. Pepper plants which were only injured were delayed in growth, resulting in loss of weight per plant. Weed control in plots chemically thinned was not as efficient as expected.

Tables 4 and 5 give the results of the third and fourth experiments on lettuce and on cabbage, respectively, when thinning was done using a knapsack sprayer. In both cases better weed control was obtained by chemical thinning than by hoeing (Figures 3 and 4). The effect of chemical weeding was reflected in fewer man hours for thinning and weeding the plots receiving pre-emergence treatment. It also appears that thinning with a hoe tends to nullify the

Table 4. Effects of pre-emergence and thinning chemical treatments on weed control, stand, and weight of lettuce plants.

Pre-emergence treatments	Pre-emergence weed control[1]	Method of thinning	Weed control after thinning[1]	Weeding and thinning—man hour/A	Plants/30 feet		Weight of 20 plants—grams
					Before thinning	After thinning	
None (check)	0	Hoed	6	38.9	75	32	325
CIPC 10 lb/A	9	Hoed	7	16.8**	73	32	300
CIPC 10 lb/A	9	Oil	8	16.2**	74	29	300
CIPC 10 lb/A	9	CIPC in oil 4 lb/A	10	16.3**	73	30	280

[1]0, no control; 10, excellent control.
**Significantly different from hoed check at 1% level.

Table 5. Response to pre-emergence treatments and chemical thinning as measured by the degree of weed control, stand, and weight of cabbage plants.

Pre-emergence treatments	Weed control after pre-emergence treatment[1]	Thinning treatments	Weed control after thinning[1]	Weeding and thinning—man hour/A	Plants/30 feet		Weight of 20 plants grams
					Before thinning	After thinning	
None (check)	0	Hoed	7	29.7	78	29	275
CDEC 8 lb/A	10	Hoed	8	12.6**	76	30	255
CDEC 8 lb/A	10	CDEC 4 lb/A	10	12.2**	80	34	290*
CDEC 8 lb/A	10	Oktone 4 lb/A	10	12.2**	79	35	355*

[1]0, no control; 10, excellent control.
*Chemically thinned plots different from plots thinned by hoeing at 5% level.
**Different from plots with no pre-emergence treatment at 1% level.

Figure 3. Chemical thinning with CDEC in oil added some residual weed control effect to the pre-emergence treatment. The check row (lower) was thinned with a hoe, which appears to destroy the action of the pre-emergence treatment; however, lettuce plants on the CDEC treated row (upper) appeared slightly stunted due to drift of the chemical.

Figure 4. Effect on weed control and on the cabbage plants when thinning was done with CDEC in oil (lower row) and when thinning was done with a hoe (upper row).

effect of the pre-emergence treatment. Wind velocity at the time of thinning the lettuce was 2 mph but did not cause significant reduction in weight. Significantly heavier cabbage plants were obtained when chemical thinning was used. This was probably due to the lack of wind drift of the thinning material, which would have damaged the crop, and/or the avoidance of root pruning which usually results when thinning is done with a hoe. The yield and quality of marketable lettuce and cabbage were not affected by the treatments.

Results of a 3 x 3 x 3 factorial experiment with cabbage are given in Table 6. Data showing no significant effect have been omitted. In Table 6, it is shown that the various seeding distances (S_0, S_1 and S_2) produced different crop population as anticipated. There was a significant increase in the number of cabbage plants where 4 pounds of CDEC (C_1) were applied as a pre-emergence treatment as compared with 8 pounds of CDEC (C_2), but this difference disappears when compared with the no CDEC treatment (C_0).

The same table shows the effects of seeding distances (S_0, S_1 and S_2), on stands of plants after thinning. Closer seeding distances (S_0–2.5 inches) produced an undesirably greater number of plants. Rates of Oktone (the thinning material) did not affect the final stand of the cabbage plants. The interaction of S x O was significant. When the seeding distance was 2.5 inches apart (S_0, closest spacing used) chemical thinning (O_1 and O_2) tended to increase the stand undesirably over the mechanically thinned. This indicates that chemical thinning was not done properly on plants 2.5 inches apart.

It is noted in Table 6 that close seeding distances resulted in an objectionably high number of doubles. A similar adverse effect was found when using chemical thinning as compared with no chemical thinning. When the number of doubles is considered, the interaction of seeding distances and rates of chemical thinning is significant. Thus when using no chemical for thinning, the seeding dis-

Table 6. Effects of three seeding distances in inches in all possible combinations with three rates of pre-emergence and three rates of thinning treatments in cabbage.

Observation	Seeding distance—inches			CDEC pre-emergence application—lb/A			Oktone thinning application—lb/A			Orthogonal comparisons		Regression and interaction	
	2.5 (S_0)	3.5 (S_1)	4.5 (S_2)	0 (C_0)	4 (C_1)	8 (C_2)	0 (O_0)	2 (O_1)	4 (O_2)	Treatments	Significance level—percent	Factor	Significance level—percent
Plants/30-foot row before thinning	88	64	55	69	72	67	——	——	——	S_0 vs S_1 & S_2 S_1 vs S_2 C_1 vs C_2	1 1 1	Quadratic regression for S and C	1
Plants/30-foot row after thinning	34	30	29	——	——	——	——	——	——	S_0 vs S_1	1	Quadratic regression for S S x O interaction	5 5
Doubles/30-foot row	5.0	2.0	1.0	——	——	——	0.6	3.8	4.2	S_0 vs S_1 & S_2 O_0 vs O_1 & O_2	1 1	Linear regression for S Quadratic regression for O S x O interaction	1 1 1
Thinning time—minutes/row	——	——	——	1.01	0.70	0.66	1.30	0.53	0.53	C_0 vs C_1 & C_2 O_0 vs O_1 & O_2	1 1	S x O interaction C x O interaction	5 1
Young plant weight grams	——	——	——	163	130	136	158	135	136	C_0 vs C_1 & C_2 O_0 vs O_1 & O_2	1 1		

tances did not influence the number of doubles significantly, but when chemical thinning was used, the number of doubles increased significantly as the seeding distance became closer.

In Table 6 it is shown that a significantly longer time was used for thinning when there was no pre-emergence weed control. The interactions of S x O and C x O are significant. The thinning time was not affected by the various distances between plants when chemical thinning was used (O_1 and O_2), but more time was required in plants 2.5 inches than at 3.5 or 4.5 inches apart when no chemical thinning was employed (O_0). The interaction of C x O indicates that when no chemical thinning was used, the time spent in thinning increased greatly in plants where no pre-emergence weed control was used.

Significantly larger plants were produced in plots receiving no pre-emergence and no chemical thinning (Table 6).

Number, weight and quality of marketable heads were not affected by any treatment or combination of treatments.

DISCUSSION

It appears that mechanical thinning tends to destroy the beneficial effect of pre-emergence herbicide treatment by disturbing the soil surface and also by bringing new weed seeds near the surface where conditions for germination are favorable. It is possible that chemical thinning adds some residual effect to the pre-emergence treatments; therefore, a more lasting weed control is obtained.

It is of interest to note that in very few cases and only under conditions conducive to damage by wind drift, were stand and weight of the plants decreased. Although the reductions in stand were significant for young plants, the final marketable yield failed to show any detrimental effect. Undesirable stands in many cases were due to the inexperience of the operator rather than to wind drift damage. This, however, is not intended to minimize the serious effect of wind drift when using chemical thinning.

When the distance between plants was 2.5 inches or less, chemical thinning tended to leave more plants, especially doubles, than was desirable. This seemed more pronounced when chemical thinning was done with a tractor. In this case even a speed of 0.64 mph seemed to be excessive and the eye and hand of the operator could not be coordinated adequately for an efficient job. It seems possible that a device for operating the solenoid valves automatically would give good results.

Thinning by hoeing in plots not treated for pre-emergence weed control took twice as long or more than in plots receiving pre-emergence treatments. This was due to the extra time necessary for hoeing the weeds.

When chemical thinning was done using a knapsack sprayer in plots treated with pre-emergence, the time spent was about equal to that required for thinning by hoeing. However, when a tractor was used for chemical thinning a tremendous saving in time was obtained.

These results appear to indicate that chemical weed control and chemical thinning are possible when using pelletized vegetable seeds. Tractor mounted and electrically operated valves (Figure 5) seem

Figure 5. **Tractor mounted and electrically operated valves proved to be efficient for thinning plants 3.5 and 4.5 inches apart.**

to be effective in thinning plants 3.5 inches or 4.5 inches apart. Wind drift of the thinning chemical was the major cause of damage to the crop. However, when the wind was not too strong this damage was not reflected in yields or quality of the marketable produce.

The experiments reported here show the possibilities of chemical thinning when using pelletized vegetable seeds. However, before this technique can be applied to field conditions further experimental work must be carried out.

SUMMARY

Chemical thinning was compared with mechanical thinning when using pelletized lettuce, cabbage and pepper seeds planted 2.5 to 4.5 inches apart. Pre-emergence weeding was obtained by using 10 pounds of CIPC for lettuce, 4 to 8 pounds of CDEC for cabbage and 10 pounds of Oktone for peppers. Chemical thinning was compared with mechanical thinning and was accomplished with an herbicide in oil solution using a knapsack sprayer and a tractor equipped with mechanical valves or with electrically operated solenoid valves.

It was found that; (1) more efficient and better weed control was accomplished with chemical than with mechanical thinning, (2) in most cases thinning did not affect stand or weight of the plants treated, (3) under conditions favorable to wind drift some temporary weight reduction of the chemically thinned plants occurred, (4) a tractor operated spray unit with electrically operated solenoid valves, check valves, and wide angle nozzles with the orifice about 3 inches from the surface of the soil and a ground speed of 0.64 mph gave excellent results for chemical thinning, (5) pre-emergence

application of herbicides when using pelletized seeds facilitated chemical thinning, (6) chemical thinning was more effective when seedlings were 3.5 and 4.5 inches apart in the row than at closer spacings, and (7) chemical thinning tended to increase the number of doubles (plants closer than ⅓ the distance for final stand) as compared with mechanical thinning, but did not affect the yields or quality of the crop.

ACKNOWLEDGMENTS

Grateful acknowledgment is due Germain's Inc. Filcoat Division and Asgrow Seed Growers for pelletizing and providing the seeds used in these experiments and John Randolph, Agricultural Engineer, of this Station, for suggesting the use of a Cole planter with modified asparagus plate.

A Critical Evaluation of the Use of Pre-emergence Herbicides for Weed Control in Cotton

W. K. Porter, Jr., C. H. Thomas, L. F. Curtis, and D. R. Melville[1]

Since 1951 a number of reports on the use of pre-emergence herbicides for cotton have been published (1, 2, 3, 4), and in several cases, these reports included data on the reduction of hand labor following the use of chemicals. In 1956, McWhorter et al. (2) reported that combining chemical treatments with cross-plowing resulted in even greater reductions of hand labor than by the use of chemicals alone. They also reported that even though the amount of hand labor was reduced, both by the use of chemicals alone and by a combination of chemical and mechanical means, a corresponding reduction in the overall weed control cost did not always occur.

Experimental Methods

The results presented in this paper cover a period of 5 years (1952 to 1956) and include data from a total of 42 experiments. The locations within the State of Louisiana, the soil class, and the number of experiments conducted during the various years at specific locations are shown in Table 1. During the years 1954 to 1956, a

Table 1. Number, soil class and location of experiments.

Location	Soil class	Year				
		1952	1953	1954	1955	1956
Bueche	Sandy loam	–	–	–	1	–
Cheneyville	Very fine sandy laom	–	–	–	1	–
Curtis	Fine sandy loam	–	–	–	4	1
Essen Lane	Silt loam	–	–	3	–	11
Perkins Road	Silt loam	–	–	–	5	–
St. Joseph	Sandy loam to silt loam	1	1	3	9	2
Total		1	1	6	20	14

number of experiments were conducted at several of the stations; however, each specific experiment was located on a slightly different soil type or was planted at a different date. For example, in 1955 and 1956, weekly planting dates were used at one location. All of the experiments reported on were conducted on soils varying from sandy loam to silt loam.

The minimum plot size used in any experiment was 2 rows wide by 65 feet long and all plots were replicated 4 times. In a number of experiments larger plots were used. Chemicals were applied in a volume of water equivalent to a broadcast rate of 40 gal/A; however, the treatments were confined to bands varying in widths from 13 to 15 in.

[1]Associate Plant Pathologist, Assistant Agricultural Engineer, Research Associate and Assistant Agronomist, respectively, Louisiana Agri. Exp. Sta., Baton Rouge.

Only the data on two materials, isopropyl N–(3–chlorophenyl) carbamate (CIPC) and the liquid formulation of 3–(3,4–dichlorophenyl)–1,1–dimethylurea (diuron) and a conventionally cultivated check will be discussed in this report. CIPC and diuron were used at broadcast rates equivalent to 6.0 and 0.75 lb/A, respectively. In the same experiments several other rates of chemicals were used; however, the rates chosen gave maximum hoe time reduction with higher rates not giving further reductions.

The hoe time information was collected in the following manner: (1) At least two hoe laborers (the number of rows per plot determined the number of laborers used) were assigned to a replication. (2) Each plot was hoed and the time recorded. (3) Hoeing within a single replication was according to a randomized plan. In all cases one labor group hoed all of the plots in a single replication. Therefore, it was not possible for one group to hoe all of a single treatment in an experiment without hoeing all other treatments. The coefficient of variability for the hoe times reported ranged from 15 to 20%. Plots were hoed only when the weeds reached a height of from 1 to 2 in.

Cultivation of chemically treated plots was accomplished by means of disc-hillers adjusted so as to remove the shoulders of the row without disturbing the drill area. Flat sweeps set directly behind the disc hillers were used to complete the cultivation of the shoulders and middles as well as to reshape the row. The check plots were cultivated according to the manner common to the experimental area. In some cases this involved flat low-crown sweep cultivation, in other cases high-crown deep plowing sweep cultivation and in others disc cultivation. In all experiments regardless of the type cultivation equipment used, the check plot treatment procedure involved "dirting" (soil moved to the drill area by the cultivation equipment for the purpose of smothering the young weeds) of the drill.

RESULTS AND DISCUSSION

Stand counts and yields were taken on 25 of the 42 experiments reported on. In no case was there any effect of the chemical treatment on either. With the exception of 1 or 2 semi-chlorotic leaves on a few plants in 2 experiments treated with diuron at Curtis, there was no injury to the cotton plants.

The average hoe labor requirements of the individual experiments are presented in Table 2. It may be seen from this table that in most cases there is considerable variation between the hoe labor requirements from one experiment to the next, even at the same location but at a different planting date. This is, of course, caused in part by variations in both soil moisture and atmospheric moisture. Also, the fluctuations between experiments are much greater between checks than between chemically treated plots.

The data presented in Table 2 have been averaged according to years and are presented in Figure 1. From this figure several points become quite apparent. The first is that the time requirement for

Table 2. Hand labor required for weed control in cotton in 42 experiments conducted in Louisiana, 1952 to 1956.

Year	Location and number	Hours hoe labor/acre		
		CIPC	Diuron	Check
1952	St. Joseph	4.0	—	32.2
1953	St. Joseph	11.0	13.0	15.0
1954	Essen Lane (1)	23.0	26.4	64.8
	St. Joseph (1)	12.9	6.0	38.6
	Essen Lane (2)	14.0	7.6	128.7
	St. Joseph (2)	8.3	7.7	34.9
	Essen Lane (3)	21.2	21.8	92.5
	St. Joseph (3)	3.5	3.1	27.1
1955	Curtis (1)	6.2	4.8	23.5
	Curtis (2)	12.6	9.1	27.0
	Curtis (3)	9.8	6.7	33.8
	Curtis (4)	4.7	4.5	16.5
	Perkins Road (1)	30.0	30.8	32.5
	Perkins Road (2)	20.4	18.3	20.4
	Perkins Road (5)	13.3	21.7	17.5
	Perkins Road (5)	10.8	13.8	14.2
	Perkins Road (2)	10.5	9.6	13.0
	St. Joseph (1)	7.3	4.4	9.2
	St. Joseph (2)	6.2	7.9	6.9
	St. Joseph (3)	8.8	7.5	11.7
	St. Joseph (4)	15.0	5.8	16.5
	St. Joseph (5)	12.1	11.6	9.2
	St. Joseph (2)	6.5	8.3	10.8
	St. Joseph (2)	9.2	11.2	16.9
	St. Joseph (9)	6.5	—	8.7
	St. Joseph (11)	5.2	4.2	5.2
	Cheneyville	8.6	9.6	9.2
	Bueche	9.4	5.8	12.9
1956	Curtis (1)	6.3	4.6	8.7
	St. Joseph (1)	6.0	7.9	18.2
	St. Joseph (2)	8.3	13.1	21.2
	Essen Lane (1)	15.2	16.4	43.4
	Essen Lane (2)	11.2	13.3	44.5
	Essen Lane (3)	9.0	14.5	35.8
	Essen Lane (4)	25.8	22.5	77.5
	Essen Lane (5)	24.2	16.7	84.2
	Essen Lane (6)	5.4	5.8	26.6
	Essen Lane (7)	12.0	4.6	42.1
	Essen Lane (8)	19.0	17.5	52.6
	Essen Lane (9)	17.9	26.5	83.5
	Essen Lane (10)	48.3	32.4	66.3
	Essen Lane (11)	10.0	5.2	48.3

hoeing chemically treated areas is remarkably constant over the period of years. In fact, with the exception of 1952, and that year's data represent only one experiment, there was only a few hours variation between the averages of the years. Secondly, there is quite a striking fluctuation between years on the time required to hoe the non-chemically treated areas. In general, the years 1952 to 1956 were rather dry during the early spring in most of Louisiana. However, in 1952, 1954, and 1956, there was considerably more early rainfall (rainfall for a period of 3 to 6 weeks after planting) than in 1953 and 1955. In both of the latter years, rainfall was so scant that cotton seed germination continued over a period of 4 to 6 weeks. As might be expected, the number of annual weeds that emerged was small. The small amount of hoe time required for the check plots further substantiates this point (Figure 1). Similarly Table 3 shows that the range, minimum-maximum hoe requirement, was narrower during an excessively dry year (1955) than on years with moderate moisture (1954, 1956).

Table 3. Range of labor requirements for non-chemically treated plots.

Year	Hours hoe labor/acre		
	Minimum	Maximum	Average
1952	—	—	32.2
1953	—	—	15.0
1954	27.1	128.7	64.4
1955	5.2	33.8	15.8
1956	8.7	84.2	46.7

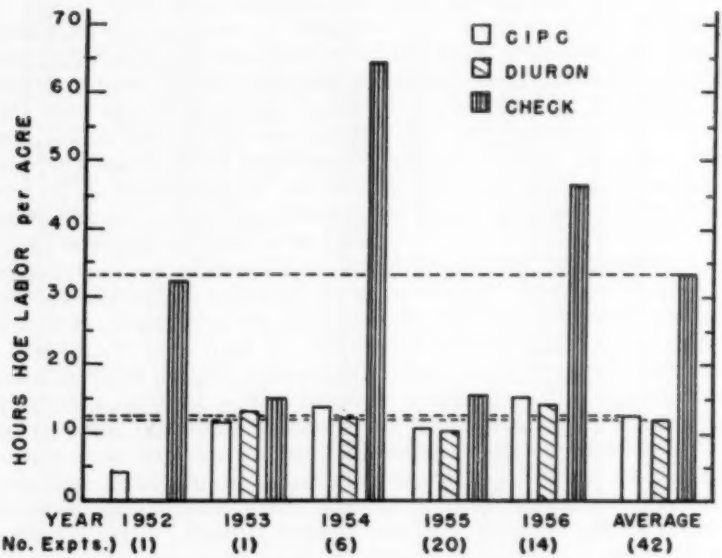


Figure 1. A comparison between the use of pre-emergence herbicides versus no herbicide in terms of the number of hours required for hoeing.

Two other points that are of interest should be considered. The first is that at the rates used in the above experiments CIPC and diuron reduced the hoe time to about the same degree (average time requirements were 12.60 and 12.06 hr/A, respectively). The second point is that the average hoe time requirement of the checks over the period of years was about 33.4 hr/A.

An overall labor saving of 20 to 21 hr/A is of definite value in approaching a complete mechanization program. However, it is necessary to consider the costs involved to determine whether or not such a labor-saving is economically sound. The following assumptions on costs as relating to a hand labor vs. chemical program are presented.

(1) CIPC @ $1.60/lb or $3.20/A.
(2) Diuron @ $6.66/lb or $1.66/A.
(3) Application and other related costs $1.00/A.
(4) Hand labor @ $0.35/hr.

From the above assumptions the so-called "break-even" point is 12 hrs/A and 7.6 hr/A, respectively for CIPC and diuron. In other words it is necessary to reduce hand labor by 12 hr/A if a chemical program using CIPC is to cost no more than a full hand labor program.

In Figure 2 the above assumptions have been combined and are plotted for the purpose of showing the economic advantage or disadvantage of using pre-emergence herbicides. This figure shows that

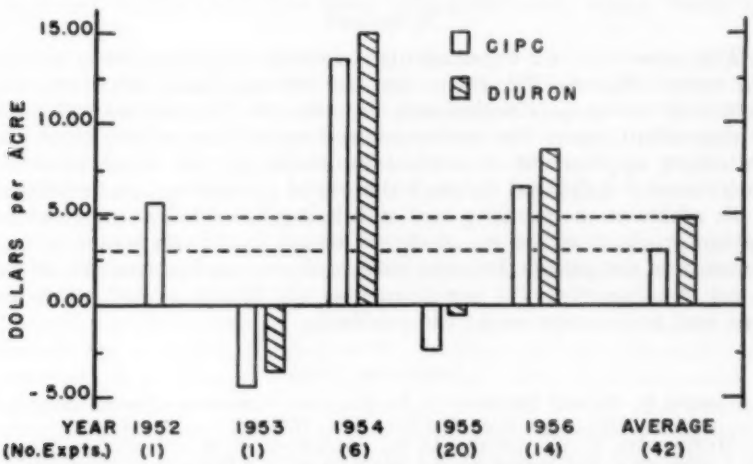


Figure 2. A comparison between the use of pre-emergence herbicides versus no herbicide in terms of the amount of money saved or lost by the use of herbicides.

in 1952, 1954, and 1956, there was a definite monetary gain as a result of the use of pre-emergence herbicides. In 1953 and 1955, there was an actual loss by use of the herbicides. However, again it should be pointed out that the 1953 data represent only one experiment. If a number of experiments had been conducted that year, the loss might have been less. Since 1953 was a very dry year, some loss would have been expected.

Figure 2 also shows that the rather small difference in the cost of diuron ($1.53/A) as compared to CIPC allows for an increased margin of gain in years in which there is a rather high weed population (1954, 1956) and helps reduce the loss on low weed population years (1953, 1955). For example in 1955, the net loss/A on CIPC treated plots was $2.34 as compared to a net loss of only $0.46/A for diuron. This figure also shows that a net gain of $3.08 and $4.80/A, respectively for CIPC and diuron as compared to no chemical treatment was obtained when all years and experiments were averaged.

All the above information shows that in addition to reducing and stabilizing the hand labor requirements of cotton, pre-emergence herbicides can help to increase the profit of production. On the other

hand, the maximum loss that could be obtained through the use of pre-emergence herbicides would amount to the cost of chemical plus application, whereas the gain has no limit.

It should be remembered that the discussions above have not considered the impact of herbicides on other phases of cotton culture. No doubt, the reduction of spring hand labor requirements could also result in more efficient utilization of other mechanical equipment, such as the cotton picker.

SUMMARY

The results of 42 experiments, conducted in Louisiana during the years 1952 to 1956, show that the average hand labor requirements of cotton production can be reduced. The actual reduction is dependent upon the environmental conditions at the time and following application of herbicides. Similarly the hand labor requirement is stabilized through the use of pre-emergence herbicides.

In addition to reducing and stabilizing hand labor required for cotton production, the use of chemicals resulted in an actual average increase in the profits. In some years and at some locations there was a net loss; however, the net gains over the 5 year period offset this loss and an average profit was realized.

LITERATURE CITED

1. CROWE, G. B., and HOLSTUN, J. T., JR. The economics of weed control in cotton. Miss. Agri. Exp. Sta. Cir. 179. 1953.
2. MCWHORTER, C. G., WOOTEN, O. B., and CROWE, G. B. An economic evaluation of various weed control practices in the Delta area of Mississippi. Proc. Southern Weed Conf., pp. 19–31. 1956.
3. PORTER, W. K., JR., HOLSTUN, J. T., JR., WOOTEN, O. B., JR., and JONES, J. K. The comparison and evaluation of chemical and mechanical methods of weed control in cotton. Proc. Southern Weed Conf., pp. 64–69. 1951.
4. PORTER, W. K., JR., THOMAS, C. H., and STAMPER, E. R. An evaluation of combinations of chemicals as pre- and post-emergence herbicides. Proc. Southern Weed Conf., pp. 65–71. 1955.

The Response of Selected Cotton Varieties to Pre-emergence Herbicides[1]

B. A. Waddle, C. Hughes, M. N. Christiansen, and R. E. Frans[2]

The use of pre-emergence herbicides to aid in the control of weeds in cotton has become an accepted production practice during the last ten years. In the process of becoming an established practice, this use of herbicides has created several new problems of a temporary nature and has been associated with stand losses in isolated cases.

Locally severe stand losses were associated with the use of pre-emergence herbicides in 1952 in the mid-South area of the cotton belt (3); however, unique climatic conditions during the planting season probably made a greater contribution. At least one official survey of losses in 1952 (6) found a varietal difference in degree of stand reduction among the many fields checked where pre-emergence herbicides were used.

Cotton varieties differ in few to many characteristics, including seedling characteristics. It should be logical to assume that a differential varietal injury due to pre-emergence herbicides could occur.

Normand (5) found no varietal differences in stand reductions attributable to CIPC (isopropyl N–(3–chlorophenyl)carbamate) or monuron (3 (p–chlorophenyl)–1,1–dimethyl urea) but suspected a varietal difference in reductions associated with DNBP (4,6–dinitro ortho secondary butylphenol). In a pilot study preceding the work reported here, Adkisson and Waddle (1) found fewer differences in stand between varieties treated with pre-emergence herbicides than between varieties receiving no herbicides. In both cases cited above, only one planting date and hence only one set of climatic conditions were sampled. Thompson et al. (7) and Hollingsworth and Ennis (4) have reported increased stand losses when DNBP was used as a pre-emergence herbicide. The latter reported excessive losses associated with high (90° F.) temperatures. By altering planting dates critical temperatures could be anticipated and varietal response differentials should be detected if they exist.

The purpose of this study was to evaluate selected cotton varieties as to herbicidal injury when dates of planting were varied so as to sample a wide range of climatic conditions.

Materials and Methods

This study was conducted at the Cotton Branch Experiment Station, Marianna, Arkansas in 1954, 1955, and 1956. The general soil type represented by this station has been classified as Richland silt loam of medium fertility. Because of rotation requirements, a different field plot was used each of the three years.

---

[1]Published with the approval of the Director of the Arkansas Agricultural Experiment Station.

[2]Associate Professor, Instructor, Graduate Assistant, and Assistant Professor, respectively, Dept. Agronomy, University of Arkansas, Fayetteville, Ark.

Seedbed preparations each year were typical of the area and consisted of bedding, applying fertilizers in the middle, harrowing, re-bedding, and harrowing ahead of planting. The time of the several operations varied according to weather conditions with one to three weeks elapsing between the final bedding operations and planting the early date of planting. No subsequent seedbed preparation was followed for the late planting except for an occasional light cultivation to keep down weeds prior to planting.

Standard two-row tractor planting equipment with the hill-drop attachment was used in 1954 and 1955. A standard one-row tractor was used in 1956. In all three years, the planting of the several varieties was completed and followed by the application of the several pre-emergence herbicides. Tractor-mounted spray equipment, operated with the power-take-off pump set at 30 psi, was used on the two-row tractor in 1954 and 1955 and on the one-row tractor in 1956. In all three years, a 12-inch roller was used to firm and even the row ahead of the nozzle placed at a sufficient height to produce a 10-inch band in 1954 and 1955, and a 12-inch band in 1956 across the center of the row. Tractor speed was regulated to deliver 12 gal/A of spray for each pre-emergence herbicide.

Three pre-emergence herbicides were used each of the three years. These were the alkanolamine salts of DNBP, CIPC, and 3–(3,4–dichlorophenyl)–1,1–dimethylurea, hereafter referred to as DNBP, CIPC, and diuron, respectively. DNBP and CIPC were applied at the rate of 9 lb/A over-all each year and diuron was applied at the rate of 1½ lb/A in 1954 and 1 lb/A in 1955 and 1956. Sufficient water was added to make the total volume of the spray mixtures equal to an application rate of 12 gal/A.

Varieties of cotton selected for this study were Fox, Deltapine 15, Empire WR, and Arkot 2–1. These varieties were chosen on the basis of maximum seedling differences observed in the pilot study completed in 1953 (1). Seeding rates were 1 bu/A each year. Varietal differences in seed size gave differential numbers of seed planted, but the same seeding rate was used in all herbicide treatments.

Planting dates were April 26, May 17, and June 7 in 1954; May 9 and June 6 in 1955; and May 8 and June 6 in 1956. The April plantings were made also in 1956, but were lost due to severe weather conditions.

The experimental design used was a split-split plot of two replications in 1954; three in 1955; and four replications in 1956. The major or main plots were planting dates, sub-plots were pre-emergence herbicide treatments (DNBP, CIPC, diuron, and none), and sub-sub plots were the four varieties. Statistical analyses were in accordance with procedures outlined by Cochran & Cox (2). Two-row varietal plots, each 50 feet in length, were used in 1954 and 1955. Single-row varietal plots, 80 feet in length, were used in 1956. In 1954, five 10-foot sections of each varietal plot were measured and staked prior to planting. In 1955 and 1956, three 10-foot sections were staked per plot. Stand counts for the five sampled areas in 1954 and the three in 1955 and 1956 were averaged and entered as plot

values. These stand counts were made twice before the first flower, with the second count taken as final.

Final stand counts were used to evaluate herbicidal injury. Conclusions drawn were based on estimates of herbicide x date and herbicide x variety interactions.

Yield of lint per acre was estimated with actual plot yields. Boll samples from each plot prior to first harvest furnished lint percentage data needed to convert plot yields to pounds of lint per acre.

RESULTS

Stand reductions attributable to herbicides applied as pre-emergence sprays were appreciable in only one of the three years included in this study and that in the June planting of 1954 with DNBP as the more damaging herbicide. Stand reductions were rather heavy (Table 1), although the injury was hardly significant statistically

Table 1. Average values in thousands of cotton plants per acre for four pre-emergence herbicide treatments and four varieties planted on different dates in 1954, 1955, and 1956.

Herbicide	Cotton variety	1954 Planting dates			1955 Planting dates		1956 Planting dates	
		April	May	June	May	June	May	June
CIPC	Fox	20.1	48.6	26.4	24.0	25.1	49.8	48.1
	Deltapine 15	18.8	47.8	25.4	27.9	31.1	45.4	62.6
	Empire WR	15.9	36.6	20.9	24.2	22.4	44.0	56.8
	Arkot 2-1	28.7	54.6	19.1	31.7	27.2	45.4	59.2
	Average	20.9	46.9	23.0	27.0	26.4	46.2	56.7
DNBP	Fox	15.4	39.2	36.9	26.4	33.4	46.6	62.7
	Deltapine 15	13.9	31.6	12.0	22.5	26.1	46.6	53.6
	Empire WR	12.8	49.4	16.2	21.6	23.8	40.9	53.9
	Arkot 2-1	20.1	49.1	3.9	37.5	19.5	49.5	40.2
	Average	15.6	42.3	17.2	27.0	25.7	45.9	52.5
Diuron	Fox	20.6	34.8	23.0	23.1	19.3	45.3	56.6
	Deltapine 15	15.4	35.3	26.1	19.6	34.7	47.5	60.7
	Empire WR	17.8	24.0	24.6	17.7	24.8	42.4	59.9
	Arkot 2-1	29.0	48.1	13.3	22.8	24.1	51.9	64.9
	Average	20.7	35.6	21.7	20.8	25.7	46.8	60.5
Check	Fox	14.1	38.4	29.0	28.9	20.5	45.3	53.5
	Deltapine 15	13.3	30.6	28.7	25.8	38.1	50.7	59.1
	Empire WR	15.9	35.0	14.6	26.0	21.8	48.8	59.1
	Arkot 2-1	20.9	61.7	20.4	31.9	21.8	55.9	55.0
	Average	16.0	41.4	23.2	28.2	25.6	50.2	56.7
Average by dates		18.3	41.5	21.3	25.7	25.8	47.2	56.6

(Table 2). It is probable that these reductions were associated with abnormally high temperatures for the first four weeks following June plantings. Climatic conditions were within normal expectations during the other two years included in this study.

When the data from each of the three years were combined, the herbicides x date of planting interaction approached significance, as shown in Table 3. This interaction represents the reduction in stand associated with diuron in May plantings; the increase in stands

Table 2. Selected mean squares from variance analyses of plants per plot following the treatment of four cotton varieties with pre-emergence herbicides in 1954, 1955, and 1956.

Source of variation	1954		1955		1956	
	Df	Mean square	Df	Mean square	Df	Mean square
Dates	2	43,312	1	2	1	14,749
Error a	2	4,773	2	7	3	10,073
Herbicides	3	1,283	3	281	3	718
H x D interaction	6	842	3	431	3	513
Error b	9	341	12	391	18	599
Varieties	3	1,971*	3	1,041**	3	276
V x D interaction	6	380	3	1,863	3	688
V x H interaction	9	629	9	84	9	493
V x H x D interaction	18	428	9	220	9	573
Error c	36	685	48	201	72	584

*Significant at the 5% level of probability.
**Significant at the 1% level of probability.

associated with CIPC in May plantings; and the reduction in stands associated with DNBP in June plantings. In 1954, plots planted in May and receiving CIPC as a pre-emergence herbicidal spray resulted in better stands than the plots receiving no herbicides. In 1954 and 1955, similar plots receiving diuron as a pre-emergence herbicide resulted in poorer stands than those receiving no herbicide. Although these stand differences were evident, only in the June planted DNBP plot of 1954 were stand reductions sufficient to affect yield of lint per acre, as shown in Tables 4 and 5.

Significant stand differences were associated with varieties in 1954 and 1955. These differences can be attributed largely to differences in number of seed planted. Stands of all plots were excellent in 1956. The variety x herbicide interaction was not significant in any of the three years nor in the combined analyses. When dates were considered also, however, a significant interaction was measured in

Table 3. Variance analysis summary of three years' data combined and converted to thousands of cotton plants per acre following the treatment of four varieties with pre-emergence herbicides on May and June planting dates.

Source of variation	Df	Mean square
Dates	1	310.32
Years	2	6,054.83
Error a	2	1,837.88
Herbicides	3	48.13
H x D interaction	3	77·37
Error b	12	23.85
Varieties	3	79.53*
V x D interaction	3	320.69**
V x H interaction	9	51.33
V x H x D interaction	9	57.61*
Error c	48	26.45

*Significant at the 5% level of probability.
**Significant at the 1% level of probability.

Table 4. Yield of lint in pounds per acre of selected treatment combinations involving herbicides, cotton varieties, and planting dates in 1954, 1955, and 1956.

Herbicide	Cotton variety	1954 Planting dates		1955 Planting dates		1956 Planting dates	
		May	June	May	June	May	June
CIPC	Ave. all varieties	626	504	1005	666	515	490
DNBP	Fox	579	347	1139	581	441	486
	Deltapine 15	664	565	1032	703	408	445
	Empire WR	626	307	949	577	514	531
	Arkot 2-1	591	287	974	591	498	425
	Average	615	376	1024	613	465	472
Diuron	Ave. all varieties	677	449	985	545	501	473
Check	Ave. all varieties	578	501	973	587	487	454
Varietal averages	Fox	620	480	1095	574	447	477
	Deltapine 15	678	499	1000	642	429	429
	Empire WR	575	446	925	628	558	521
	Arkot 2-1	624	406	966	568	533	461
Average by dates.....		624	458	997	603	492	472

Table 5. Selected mean squares from variance analyses of yield of lint per acre following the treatment of four cotton varieties with pre-emergence herbicides in 1954, 1955, and 1956.

Source of variation	1954		1955		1956	
	Df	Mean square	Df	Mean square	Df	Mean square
Dates.....	2	1,251,174	1	3,720,150**	1	12,403
Error a.....	2	1,336,077	2	12,602	3	40,378
Herbicides.....	3	179,919*	3	25,860	3	7,534
H x D interaction.....	6	92,370	3	10,814	3	2,490
Error b.....	9	45,087	12	11,913	18	14,552
Varieties.....	3	28,150	3	26,079**	3	8,828
V x D interaction.....	6	68,180	3	53,296**	3	15,577**
V x H interaction.....	9	86,581	9	4,953	9	3,542
V x H x D interaction.....	18	81,222	9	11,862*	9	3,242
Error c.....	36	46,443	48	5,102	72	3,822

*Significant at the 5% level of significance.
**Significant at the 1% level of significance.

the combined data, as shown in Table 3. This interaction reflects largely the deleterious effect of DNBP on the June planted Arkot 2–1 variety in 1954. In the combined analyses, the variety x dates interaction was highly significant. As shown in Table 1, this interaction reflects the excellent stands obtained for the Arkot 2–1 variety obtained in the May plantings, as contrasted with the poor stands obtained when this variety was planted in June. In contrast, the Fox variety gave acceptable stands for May planting dates and higher than average stands when planted in June.

DISCUSSION AND CONCLUSIONS

Varieties of varying seedling characteristics, and planting dates expected to sample varying environments, were brought together with three pre-emergence herbicides in this study. These variables should have revealed any differential varietal responses to such herbicides. However, the variety x herbicide interactions as estimated in this study were not significant. On the basis of these data, it was concluded that the four varieties included in this study were not affected differentially by the three pre-emergence herbicides used.

The herbicide x planting date interaction approached significance in terms of final stand counts when the three years' data were combined. Stand reductions associated with herbicides were found only when stand reductions were rather severe because of factors other than herbicides. On the basis of the herbicidal responses measured in this study, it was concluded that the use of pre-emergence herbicides should cause no stand reductions in a normal planting season. A deleterious environment during the seedling stage of cotton may be aggravated, however, by the use of these chemicals.

Stand reductions associated with pre-emergence herbicides were evident in two of the three years included in this report. In only one combination (the June planted Arkot 2–1 variety treated with DNBP in 1954) was the final yield of lint per acre reduced appreciably because of stand reductions. Until more information is available to define conditions wherein stand reductions should result in yield reductions, the conclusion drawn here was that pre-emergence herbicides, even though associated with stand reductions, did not seriously affect the final lint yields.

SUMMARY

Cotton varieties having varying seedling characteristics and planted on different dates were not differentially affected by pre-emergence herbicides in 1954, 1955, and 1956 tests. CIPC, DNBP, and diuron as pre-emergence herbicides caused no more stand reduction than plots receiving no treatment in a normal planting season. A deleterious environment, however, may be aggravated by these chemicals in terms of stand reductions. Such reductions rarely are sufficient to affect yields of lint per acre.

LITERATURE CITED

1. ADKISSON, P. L., and WADDLE, B. A. Varietal reactions to pre-emergence herbicide sprays. Proc. Assn. Southern Ag. Workers. pp. 178–179. 1954.
2. COCHRAN, WILLIAM G., and COX, GERTRUDE M. Experimental designs. John Wiley & Sons, Inc. 454 p. 1950.
3. GARRARD, W. M. Pre-emergence chemical application is said to cause damage to many cotton fields. Cotton Digest 24:9. 1952.
4. HOLLINGSWORTH, EVERETT B., and ENNIS, W. B., JR. Some studies on vapor action of certain dinitro compounds upon young cotton seedlings. Proc. Southern Weed Conference. pp. 23–31. 1953.

5. NORMAND, W. C. A study of the interaction of cotton varieties and pre-emergence herbicides. Proc. Southern Weed Conference. pp. 129–133. 1954.
6. STAMPER, E. R., SMILIE, JOSEPH L., and MAYEAUX, M. M. The reaction of cotton varieties to pre-emergence herbicides. Proc. Southern Weed Conference. pp. 38–39. 1953.
7. THOMPSON, J. T., HAUSER, ELLIS W., and STACY, S. V. Chemical weed control in Georgia. Proc. Southern Weed Conference. pp. 115–118. 1954.

The Response of Certain Crops to 2,4–Dichlorophenoxyacetic Acid in Irrigation Water. Part II. Sugar Beets[1]

V. F. Bruns[2]

The use of 2,4–dichlorophenoxyacetic acid (2, 4–D) for weed control in irrigated regions, especially on ditch banks, provides possibilities of contaminated irrigation water. A series of investigations has been conducted in the field to determine the response of certain crop plants to applications of 2,4–D in irrigation water, particularly at rates totaling herbicidal dosages. The first investigation dealt with Red Mexican beans and the results were published in 1954 (1). This report deals with sugar beets, a root-type of crop plant.

Watson (4) applied an amine form of 2,4–D to carrots, parsnips, beets, and several members of the cabbage family in the greenhouse by three different methods. One or two drenches to the soil, simulating irrigation with contaminated irrigation water, at concentrations of 5 to 10 ppm was the most satisfactory method for producing root galls. Plants which produced galls failed to show foliage symptoms typical of 2,4–D injury. Root growth was inhibited, especially at higher concentrations. Furthermore, a considerable number of seedlings and small plants were killed. This greenhouse study closely paralleled the field study reported herein.

Materials and Methods

With slight modification, the same materials and methods were used as previously described (1). These investigations were conducted on Sagemoor very fine sandy loam soil. This soil is low in organic matter, with a depth of 60 inches to bedrock.

After applying 600 pounds of ammonium nitrate (33 percent nitrogen) per acre on March 7, 1952, the land was plowed and harrowed. On April 14, the experimental area was tandem disked and cross-harrowed. Then 24 plots (6 plots within 4 blocks), each 10 by 20 feet, were laid out on contour with a zero grade. The borders of adjacent plots were at least 48 inches apart; the alleyways between blocks were 10 feet wide. After the plots were ditched for irrigation, sugar beets were seeded on April 15 with a hand-seeder in rows 24 inches apart and 20 feet long (4 rows per plot). All plots received 3 acre-inches of irrigation water immediately after the sugar beets

[1]Contribution of the Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture, and the Washington Agricultural Experiment Stations cooperating. Scientific Paper No. 1572, Washington Agricultural Experiment Stations. This work was supported by a contract with the Chemical Corps, Fort Detrick, Frederick, Maryland.

[2]Agronomist, Field Crops Research Branch, Agricultural Research Service, Irrigation Experiment Station, Prosser, Washington. The author wishes to express his appreciation to F. L. Timmons, F. G. Viets, C. L. Crawford, J. S. Robins, and C. J. Cox of the Agricultural Research Service, U. S. Department of Agriculture, and H. P. Singleton and Alf Hammer of the State College of Washington for their assistance in these investigations. H. W. Potter (WSC) prepared the photographs appearing in this report.

were seeded. Lack of precipitation and irrigation water prevented seeding of beets at an earlier, more desirable date. Because of adverse weather conditions, insects, birds, and rodents, poor stands of sugar beets were obtained.

Six 600-gallon tanks, equipped with valves, hoses, and boom attachments, were used throughout the experiment for applying irrigation water and 2,4–D (Figure 1). All plots received normal irrigations before and after the 2,4–D treatments. Normal field cultivation was simulated by the use of hand tools.

Figure 1. Metal tanks, equipped with valves, hoses, and boom attachments were used to apply irrigation water and 2,4–D.

Six different plot treatments were randomized within the four separate blocks. These treatments included two rates of 2,4–D (2 and 6 pounds of the acid dissolved with triethanolamine per acre), two stages of growth (seedling and 1-inch diameter), and an untreated check. A sixth treatment was a repeated application of 2,4–D approximately 4 weeks after an initial application at the rate of 2 pounds per acre at the 1-inch diameter stage.

On May 12, when sugar beets were in the 2- to 4-leaf stage, hereafter referred to as the seedling stage, the first 2,4–D treatments were made at rates of 2 and 6 pounds per acre in 3 acre-inches of irrigation water (approximately 3 and 9 ppm by weight). Plots scheduled to receive 2,4–D applications at the 1-inch diameter stage were treated on June 25. At this time, beets ranged from 0.5 to 1.5 inches in diameter. The same procedures, methods, and materials were used in making these applications as were used in making the treatments during the seedling stage. Plots scheduled to receive a second treatment were re-treated on July 22. The irrigation furrows were dammed at each end of the plots and the water flow from the tanks could be regulated and adjusted. Thus, the problem of measuring runoff water and discarding the effluent was eliminated.

Because of the relatively poor and erratic stands of sugar beets, actual plant counts on individual plots were taken and recorded at monthly intervals throughout the course of the experiment. At harvest time (October 4), beets were counted and weighed so the mean weights per beet for each plot could be computed. These criteria were considered more reliable for evaluating the effects of the treatments than yields in tons per acre. The beets were then taken to the laboratories of the Utah-Idaho Sugar Company, Toppenish, Washington, where sucrose determinations were made by the polariscope method.

As an exploratory test, two additional plots of sugar beets (each containing 4 rows, 24 inches apart and 20 feet long) were used for nitrate-nitrogen studies. One plot received 2 pounds of 2,4–D per acre in 2 acre-inches of irrigation water on July 2, when beets averaged 1 inch in diameter. The other plot was used as an untreated check.

Leaf and petiole samples (10 from each row) were collected at random from each plot at intervals as follows: 0, 3, 6, 12, 24, 48, and 90 days after treatment. After collection, the leaves and petioles were separated immediately and then placed in a drying oven (80° C.) until thoroughly dry. After the drying process, the samples were ground finely and stored in glass bottles. The nitrate-nitrogen determinations were made in duplicate by the phenoldisulphonic acid method.

EXPERIMENTAL RESULTS AND DISCUSSION

In evaluating reductions in stand caused by the 2,4–D applications, the observed percentage reductions were transformed to angles (Arc sin $\sqrt{\text{Percent reduction}}$). This transformation was used because of the wide range in observed reductions (7 to 92 percent). Large differences in final stand also resulted from the treatments. Competitive effects resulting from these stand differences logically would influence the rate of growth of the beet roots and the sucrose content. Therefore, the observed mean weights per beet and sucrose contents were adjusted by means of covariance analyses to compensate for population differences and to permit evaluation of treatment effects independent of stand differences. In each case, the linear adjustment for stand differences was highly significant. Effects of the treatments on stand and beet weight are shown in Table 1.

Treatments at seedling stage.

The 2,4–D treatments during the seedling stage caused the greatest reduction in stands of sugar beets. Within 3 days after the applications, some of the seedlings became somewhat distorted and flaccid, particularly on plots treated at the 6-pound rate. The lethal action of the 2,4–D (complete desiccation) was most pronounced from 1 to 3 weeks after treatment. Marked reduction in stands occurred on plots treated at the 2-pound and 6-pound rates as indicated by the angles of 57 and 77, respectively, at harvest time.

Table 1. The effect of 2,4-D in irrigation water on the stand and yield of sugar beets.

2,4-D treatment	Number of sugar beet plants per plot						Percent reduction in stand		Mean wt. per beet (lb.)	
	Initial	Surviving—1952								
	5/12/52	5/27	6/25	7/22	8/15	10/4	Observed	Angle	Observed	Adjusted
Seedling stage										
2 lb/A.	78	48	26	24	20	22	69	57**	2.68	2.35
6 lb/A.	73	20	6	5	6	5	92	77**	2.47	1.60**
1 inch dia. stage										
2 lb/A.	58	—	—	45	41	42	31	33**	1.38	1.67*
6 lb/A.	48	—	—	25	20	20	61	52**	1.35	0.96**
2 lb/A + re-treatment. . .	77	—	—	68	56	58	25	30*	1.35	2.10
Untreated check	53	53	52	52	50	50	7	13	1.68	2.19
L.S.D.: 5% level								14		0.41
1% level								20		0.57
C.V.								22%		15%

*P < 0.05
**P < 0.01

The growth and development of plants surviving the 2-pound application at the seedling stage were not inhibited, as measured by mean weight per harvested beet. However, an occasional plant among those surviving the 6-pound treatment developed peculiarly malformed foliage as the season advanced (Figure 2). A significant reduction in the adjusted mean weight per beet further reflected an inhibition of growth and development by this treatment.

Treatments at 1-inch diameter stage.

Within 1 or 2 days after 2,4–D treatments at the 1-inch diameter stage, the beet plants began to wilt and become prostrate. Another characteristic symptom was chlorosis or yellowing of the leaves. Beets which were less than 1 inch in diameter appeared to be affected much more readily by the 2,4–D treatments than beets which were more than 1 inch in diameter.

The reduction in stand of beets on plots receiving the 2- and 6-pound rates of 2,4–D per acre during the 1-inch diameter stage reached significance at the one percent level (angles 33 and 52, respectively). While both treatments inhibited and delayed the growth and development of surviving plants, the 6-pound rate was more damaging as indicated by the decrease in adjusted mean weights per beet. Beets surviving the treatments at the 1-inch diameter stage had less time to recover and develop before harvest than those surviving the seedling stage treatments. This shorter time for recovery and growth may explain in part the lower beet weights in plots sprayed at the 1-inch stage.

A decrease in stand resulted from the application of 2 pounds of 2,4–D per acre during the 1-inch diameter stage plus a re-treatment at the same rate approximately 4 weeks later. However, because of population differences, no significant reduction in mean weight per

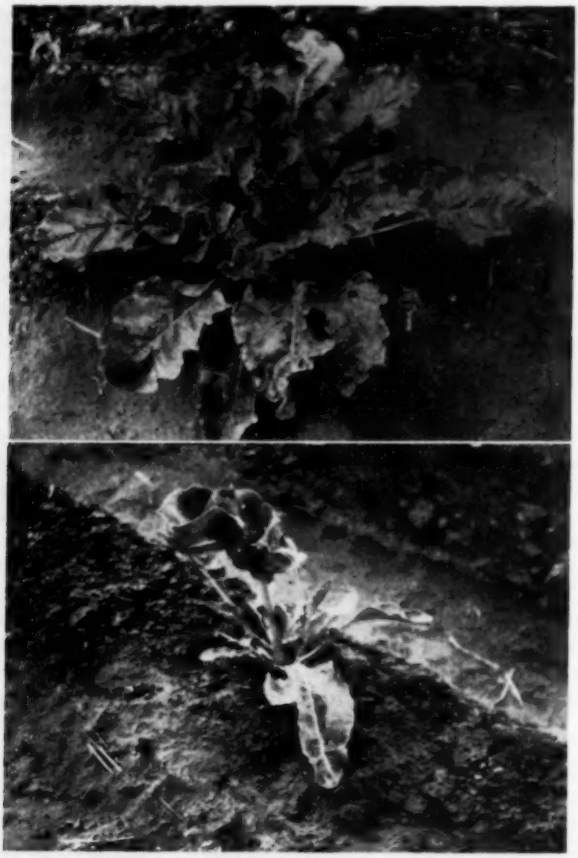


Figure 2. Top: Untreated check plant. Bottom: Malformed foliage developed on a few of the plants surviving the 6-pound treatment at the seedling stage.

beet was apparent. Only a few small plants that had been injured severely by the initial treatments were visibly affected by the re-treatments.

On some of the treated plots, especially those treated during the 1-inch diameter stage, an occasional plant developed new growth after all of the initial top growth appeared dead. This growth developed from the buds on the crowns of plants whose underground portions had not been destroyed completely and accounts for any increase in stand counts during the season as shown in Table 1. Complete desiccation of underground portions as well as top growth was a characteristic of plants that had received lethal dosages of 2,4–D during the 1-inch diameter stage. Abnormal growths on the underground portion of plants which survived the treatments were found on only two or three beets. These abnormalities were typical

symptoms of a bacterial disease of sugar beets, commonly known as crown gall, and were not attributed to the 2,4–D treatments.

Effects on sucrose content of beets.

The effects of the treatments on sucrose content of the beets are shown in Table 2.

Table 2. The effect of 2,4-D in irrigation water on the sucrose content of sugar beets.

2,4-D treatment	Mean number beets per plot	Percent sucrose	
		Observed	Adjusted
Seedling stage			
2 lb/A	22	13.8	14.12
6 lb/A	5	13.3	14.11
1 inch dia. stage			
2 lb/A	42	13.9	13.62
6 lb/A	20	12.2	12.58**
2 lb/A + retreatment	58	14.3	13.56
Untreated check	50	14.5	14.00
L.S.D.: 5% level			0.84
1% level			1.18
C.V.			4%

**$p < 0.01$.

In terms of adjusted means, the percentage sucrose in the harvested beets was not decreased by the 2,4–D treatments at the seedling stage. However, the sucrose content was reduced significantly when 2,4–D was applied at the rate of 6 pounds per acre at the 1-inch diameter stage of development. Although not statistically significant, a trend toward slightly lower percentages of sucrose in beets from plots treated at the 2-pound rate during the 1-inch diameter stage was noted. These results suggest that the shorter time for recovery between treatment at the 1-inch diameter stage and harvest of plants surviving the 2,4–D applications, particularly the 6-pound rate, not only contributed to the decrease in beet weights but also influenced the sucrose content. These deductions were substantiated further by the supplemental studies involving nitrate-nitrogen content of the leaves and petioles.

Effects on nitrate-nitrogen content of leaves and petioles.

The effects of 2 pounds of 2,4–D in irrigation water, applied at the 1-inch diameter stage, on the nitrate-nitrogen content of sugar beet leaves and petioles are presented graphically in Figure 3. The nature and design of this exploratory test precluded the application of statistical analyses. Nevertheless, the presentation of general observations and of trends exhibited by the data may be of considerable practical value and may stimulate more precise research along similar lines.

The nitrate-nitrogen content of both leaves and petioles was exceptionally high. This may be attributed to late planting of the

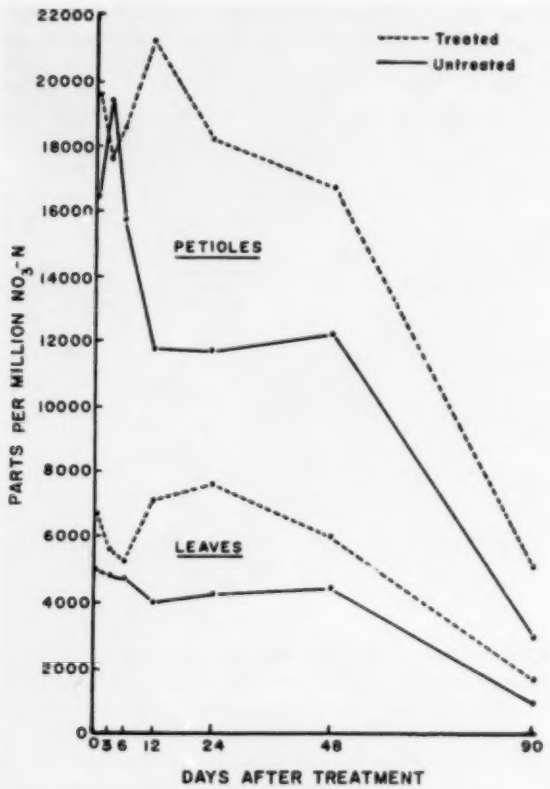


Figure 3. Nitrate-nitrogen levels in sugar beet leaves and petioles after treatment with 2,4–D (2 lb/A) in irrigation water.

beets on new land which had received a total of 300 pounds of nitrogen per acre during 1951 and 1952. Only one crop, beans in 1951, was produced on the area before the sugar beets.

With the introduction of 4 ppm of 2,4–D in a nutrient solution, Freiberg and Clark (2) found that the nitrate-nitrogen content in the leaves, petioles, stems, and roots of treated soybean plants was significantly lower 4 days after treatment. Whether the noted similar decline in nitrate-nitrogen level of beet leaves and petioles during the first few days of this experiment was caused by the 2,4–D treatment or by growth differences and/or sampling error could not be determined.

Slight chlorosis and some distortion in the foliage of treated plants was first noted within about 1 week after the 2,4–D application. Analyses of leaves and petioles collected 12 days after the application showed a marked difference in nitrate-nitrogen between the treated (T) and untreated (C) plants. Although petioles ex-

hibited higher concentrations of nitrate-nitrogen than leaves, the trend in results was similar for both. On a dry weight basis, the level of nitrate-nitrogen was approximately 80 percent higher in tissue from treated plants than in tissue from untreated checks (T–C = 7133–3995 ppm for leaves, 21,181–11,713 ppm for petioles). At this time, rather extensive damage to the root systems was observed on the treated plot. Undoubtedly the absorbing capacities of the roots were changed. Also, the possibilities of a decrease in carbohydrates and changes in concentrations of other organic components, particularly nitrogenous compounds, were recognized as complex factors which probably contributed to the differences in the nitrate-nitrogen levels.

After 48 days, the nitrate-nitrogen levels in leaves and petioles of treated plants had declined while the level in that of untreated plants had remained nearly constant. The difference in nitrate-nitrogen levels was from 35 to 38 percent (T–C = 6045–4462 ppm for leaves, 16,768–12,183 ppm for petioles). During the 2- to 3-week period preceding this sampling date, a number of plants on the treated plots died. Surviving plants showed varying degrees of recovery and growth.

At harvest time (90 days after treatment), the nitrate-nitrogen levels in the tissue of both treated and untreated plants had decreased appreciably (T–C = 1633–974 ppm for leaves, 5151–2964 ppm for petioles). Although the differences in levels between treated and untreated tissue had increased again in terms of percentage (approximately 70 percent), the differences had decreased in terms of parts per million. Late growth and development of plants on the treated plot during the last 6 weeks of the test period as well as the reduction in stand perhaps contributed to the differences in nitrate-nitrogen levels at the time of harvest.

Of corresponding interest, Stahler and Whitehead (3) collected and analyzed samples of sugar beet leaves from seven different fields that had been accidentally sprayed with 2,4–D, as well as from adjacent unsprayed fields. The dried leaves of sprayed plants contained an average of 4.50 percent of potassium nitrate, with a variation of 1.81 to 8.77 percent. Those of unsprayed plants contained an average of 0.22 percent. The minimum lethal concentration of potassium nitrate for ruminants (nitrates are changed to poisonous nitrites in the rumen) was tentatively set at 1.5 percent.

SUMMARY

1. Applications of 2,4–D at rates of 2 and 6 pounds per acre in 3 acre-inches of irrigation water were lethal to a high percentage of sugar beet plants when applied at the seedling stage.

2. Similar treatments at the 1-inch diameter stage also caused significant reductions in stands.

3. Only a few small plants severely injured by the initial applications of 2 pounds of 2,4–D per acre during the 1-inch diameter stage were visibly affected by a re-treatment approximately 4 weeks later.

4. The sucrose content of harvested beets was reduced significantly by the 6-pound treatment at the 1-inch diameter stage only.

5. Chemical analyses of leaf and petiole samples collected during the season indicated a higher level of nitrate-nitrogen in treated than in untreated tissue beginning 6 to 12 days after 2 pounds of 2,4–D per acre were applied in irrigation water at the 1-inch diameter stage.

6. The mean weight per beet and the sucrose content at harvest time were highly correlated with the final stand. These correlations as well as the observed nitrate-nitrogen differences indicate that stand differences resulting from the 2,4–D treatments were important in the experiment.

7. Reductions in adjusted beet weights indicate that the 6-pound rate of treatment at the seedling stage and both rates of treatment at the 1-inch diameter stage retarded the growth rate of surviving beets.

8. Wilting, chlorosis, prostration, and desiccation were the principal symptoms of 2,4–D damage. Malformation of top-growth, a typical reaction of many species of plants to foliage applications of 2,4–D, was observed in only a few plants. Only 2 or 3 beets developed abnormalities in the form of galls and these were not attributed to the 2,4–D treatments.

LITERATURE CITED

1. BRUNS, V. F. The response of certain crops to 2,4–dichlorophenoxyacetic acid in irrigation water. Part I. Red Mexican beans. Weeds 3:359–376. 1954.
2. FREIBERG, S. R., and CLARK, H. E. Effects of 2,4–dichlorophenoxyacetic acid upon the nitrogen metabolism and water relations of soybean plants grown at different nitrogen levels. Bot. Gaz. 113:322–333. 1952.
3. STAHLER, L. M., and WHITEHEAD, E. I. The effect of 2,4–D on potassium nitrate levels in leaves of sugar beets. Sci. 112:749–750. 1950.
4. WATSON, R. D. Galls similar to crown gall and nematode injury produced by 2,4–D. Plant Disease Reporter, 39:391–394. 1955.

News and Notes

Titles of all papers intended for presentation at the meeting of the WSA to be held January 13, 14 and 15 at the Peabody Hotel in Memphis, Tennessee, in conjunction with the Southern Weed Conference, should be in the hands of the sectional program chairmen not later than August 1, 1957. Three copies of an abstract, not to exceed 300 words, should accompany the title.

The Proceedings of the Third British Weed Control Conference, held in 1956, may now be obtained on remittance of 2 pounds, 2 shillings, by addressing the British Weed Control Council, Cecil Chambers, 86 Strand, London, W. C. 2., England.

L. S. Gleason has accepted a position with the Monsanto Chemical Company, St. Louis, Missouri in herbicide development. He was formerly with the Rockefeller Foundation, Mexico City, Mexico.

Herman E. Meadows and George F. Ham have been appointed to the technical service staff of Diamond Alkali Co.'s Chlorinated Products Division. Both are working in the company's herbicidal program.

E. A. Schnieder is now with Geigy Agricultural Chemicals, New York City, where he is engaged in herbicide development work.

Richard Hart has been employed by the American Chemical Paint Co., Ambler, Pennsylvania to conduct its primary screening work for herbicides. He was formerly a graduate student at Purdue University.

L. L. Danielson, formerly with the Virginia Truck Crops Exp. Station, Norfolk, Virginia, joined the Weed Investigations Section, ARS, USDA, in March, 1957. He will be responsible for weed research in horticultural crops at Beltsville, Maryland.

Edward L. Robinson joined the Weed Investigations Section, ARS, USDA, in February, 1957. He will be stationed at Whiteville, North Carolina, and will be concerned with cooperative studies on the control of witchweed with the North Carolina Agri. Exp. Station.

W. C. Robocker, Weed Investigations Section, ARS, USDA, was transferred from Reno, Nevada, to Pullman, Washington, where he will be engaged in cooperative work on the control of weeds on rangelands with the State College of Washington.

William F. Meggittt joined the Weed Investigations Section, ARS, USDA, in March, 1957. He will be located at Rutgers University, New Brunswick, N. J. and will be especially concerned with weed control in horticultural crops.

Howard Morton, formerly with the Idaho Agri. Exp. Station at Twin Falls, has been employed by the Weed Investigations Section, ARS, USDA, and will be stationed at College Station, Texas where he will be concerned with the control of weeds and brush in pastures and rangelands.

The officers of the WSA and the several weed control conferences for 1957 are as follows:

Weed Society of America

President—W. B. Ennis, Jr., Weed Investigations Section, ARS, USDA, Beltsville, Maryland.
Vice-president—A. S. Crafts, Dept. of Botany, Univ. of California, Davis.
Secretary—W. C. Shaw, Weed Investigations Section, ARS, USDA, Beltsville, Maryland.
Treasurer & Business Mgr.—W. C. Jacob, Dept. of Agronomy, Univ. of Illinois, Urbana.
Next meeting—January 13, 14 and 15, 1958, Memphis, Tennessee.

Northeastern Weed Control Conference

President—C. L. Hovey, Eastern States Farmer's Exchange, W. Springfield, Massachusetts.
Vice-president—S. N. Fertig, Dept. of Agronomy, Cornell Univ., Ithaca, New York.
Secretary—R. J. Aldrich, Farm Crops Dept., Rutgers Univ., New Brunswick, New Jersey.
Treasurer—D. A. Schallock, Farm Crops Dept., Rutgers Univ., New Brunswick, New Jersey.
Next meeting—January 9, 10 and 11, 1958, New Yorker Hotel, New York City.

Southern Weed Conference

President—E. G. Rodgers, Dept. of Agronomy, Univ. of Florida, Gainesville.
Vice-president—Richard Behrens, Dept. of Botany and Plant Phys., Texas A. & M. College, College Station, Texas.
Secretary-Treasurer—Walter K. Porter, Jr., Louisiana State Univ., Baton Rouge.
Next meeting—January 13, 14 and 15 in Memphis, Tennessee.

Western Weed Control Conference

President—Henry Wolfe, Dept. of Agronomy, Washington State College, Pullman.
Vice-president—Dick Fosse, American Chemical Paint Co., Denver, Colorado.
Secretary-Treasurer—W. R. Furtick, Farm Crops Dept., Oregon State College, Corvallis.
Next meeting—March 18, 19 and 20, 1958, Davenport Hotel, at Spokane, Washington.

North Central Weed Control Conference

President—F. W. Slife, Dept. of Agronomy, Univ. of Illinois, Urbana.
Vice-president—Lyle Derscheid, Dept. of Agronomy, South Dakota State College, Brookings.

Secretary-Treasurer—Dwight Lambert, Nebraska Dept. of Agriculture and Inspection, Lincoln.
Next meeting—December 10, 11 and 12, 1957, Municipal Auditorium, Des Moines, Iowa.

Western Canadian Weed Control Conference

Chairman—N. F. Putnam, Field Crops Commissioner, Dept. of Agriculture, Victoria, B. C.
Sec.-Treas.—E. C. Hughes, Field Crops Branch, Dept. of Agriculture, 70 Eighth St., New Westminster, B. C.
Next meeting—November 26 and 27, 1957, at the Empress Hotel, Victoria, B. C.

Sustaining Members

American Chemical Paint Company, Ambler, Pennsylvania
American Cyanamid Company, New York, New York
American Smelting and Refining Co., Central Research Laboratories, South Plainfield, New Jersey
Asplundh Tree Expert Company, Jenkintown, Pennsylvania
Association of American Railroads, Chicago, Illinois
Chemical Insecticide Corp., Brooklyn, New York
Chipman Chemical Company, Inc., Bound Brook, New Jersey
Crag Agricultural Chemicals Division, Carbide and Carbon Chemicals Co., New York, New York
Deere and Company, Product Research Dept., Moline, Illinois
Diamond Alkali Company, Cleveland, Ohio
The Dow Chemical Company, Midland, Michigan
E. I. duPont deNemours & Company, Inc., Grasselli Chemicals Dept., Wilmington, Delaware
G.L.F. Soil Building Service, Ithaca, New York
Geigy Agricultural Chemicals, Div. of Geigy Chemical Corp., Yonkers, New York
Hercules Powder Company, Wilmington, Delaware
International Harvester Company, Chicago, Illinois
Monsanto Chemical Company, St. Louis, Missouri
National Aluminate Company, Chicago, Illinois
Olin Mathieson Chemical Corp., Baltimore, Maryland
O. M. Scott and Sons Company, Marysville, Ohio
Spraying Systems Company, Bellwood, Illinois
Stauffer Chemical Company, New York, New York
Swift and Company (Plant Food Division), Chicago, Illinois
United States Borax and Chemical Corp., Los Angeles, California

BIBLIOGRAPHY OF WEED INVESTIGATIONS
for
October, November, December, 1956

Table of Contents

		Reference Number
I.	Economic Aspects and General Weed Problems	1
II.	Botany of Weeds	
	A. Classification and Identification	42
	B. Ecological Investigations and Surveys	44
	C. Physiological Investigations	47
	D. Morphological and Anatomical Investigations	119
	E. Weed Seed Investigations	127
III.	Weed Control	
	A. Cultural	133
	B. Chemical	
	1. Weeds in field crops	138
	2. Weeds in horticulture, ornamental and vegetable crops	188
	3. Weeds in grasslands, including grass-legume pastures, rangeland, turf, lawns, and cemeteries	208
	4. Weeds in specialized areas, including ditchbanks, canal ditches, fencerows, rights-of-way, irrigation ditches, and cities	219
	5. Woody plants	227
	6. Aquatic weeds	246
	7. Specific weeds	251
	C. Biological	305
IV.	Chemical and Biochemical Investigations	307
V.	Special Characteristics of Weeds	
	A. Poisonous Plants and Their Control	312
	B. Uses of Weeds	
	C. Pathological and Entomological Relationships	
VI.	Nature and Properties of Chemicals Used as Herbicides	326
VII.	Effect of Herbicides on Soils, Livestock, and Humans	350
VIII.	Equipment, Methods of Application, and Herbicidal Calculations	356
IX.	Legal Aspects	381

Prepared By
UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service
Crops Research Division

This bibliography of current literature on weeds and their control is issued as a service to those engaged in weed research in the United States and other countries. In issuing this bibliography the Crops Research Division, Agricultural Research Service, U.S.D.A. does not assume responsibility for the subject matter cited.

Beltsville, Maryland

I. Economic Aspects and General Weed Problems

1. ANDERSON, E. G. What weeds cost us in Canada. Calif. Weed Conf. Proc. 8:34–45. Ref. 1956.
2. BEREZOVSKIĬ, M. IA. Herbicides are an important instrument in the effort to increase the harvest. (In Russian.) Sovkhoz. Proizvodstvo 6:12–17. June 1955.
3. CALIFORNIA WEED CONFERENCE. Joint meeting of the fifteenth Western Weed Control Conference and the Eight California Weed Conference, Sacramento, California, February 15–17, 1956. Sacramento, 1956. 181 p.
4. CHESALIN, G. A. At the Conference on Chemicals for Weed Control. (In Russian.) Zemledelie 4 (6):123–125. June 1956.
5. ECKSTEIN, Z. Some problems of obtaining weed killers. III–IV. (In Polish.) Rocz. Chem. 30:627–635. Ref. 1956.
6. FAO PLANT protection bulletin 4:129–144. June 1956.
7. GILCREAS, F. W. Public health aspects of weed control. South. Weed Conf. Proc. 9:250–253. 1956.
8. JENSEN, A. O. Industry: weed control—what is being done and what it costs. Calif. Weed Conf. Proc. 8:83–86. 1956.
9. JOHNSTON, A. N. The place of agricultural chemicals in weed control. (Sum.) Agr. Bur. N.S. Wales. State Conf. Hawkesbury Agr. Col. 32: 11–14. 1956.
10. KLINGMAN, G. C. The obstinate weed. South. Weed Conf. Proc. 9:1–3. 1956.
11. MATTHEWS, L. J. Chemical methods of weed control. New Zeal. Dept. Agr. B. 329, 100 p. 1956.
12. MILLER, M. D. Glenn County Extension weed problem. Calif. Weed Conf. Proc. 8:81–83. 1956.
13. MYRICK, D. C. Economic studies of weed problems. Calif. Weed Conf. Proc. 8:45–47. 1956.
14. NORTHERN IRELAND. MINISTRY OF AGRICULTURE. Weed menace. North. Ireland. Min. Agr. Mon. Agr. Rpt. 31:74–77. July 1956.
15. PARKER, M. W. Future prospects for chemical weed control in the South. South. Weed Conf. Proc. 9:4–9. 1956.
16. PRESTON, S. W. Effective use of herbicides. (Sum.) Agr. Bur. N.S. Wales. State Conf. Hawkesbury Agr. Col. 32:15–19. 1956.
17. PRIMOST, E. Versuch zur wirkung von Dicopur auf rotklee. Pflanzenschutzberichte 17:75–80. Sept. 1956.
18. PUTNAM, N. F. Weed control activities in British Columbia. Canada. Natl. Weed Comt. West. Sect. Proc. 9:49–51. May 1956.
19. PUTTARUDRIAH, M. Notes on the preliminary experiments with chemical weed killers. Mysore Agr. J. 31:91–96. Apr./June 1956.
20. RANDLE, S. B. Pesticides—1955; economic poisons. N. J. Agr. Expt. Sta. Insp. Ser. 63, 32 p. May 1956.
21. RICHTER, K., and SCHILLER, K. Untersuchungen zur ermittlung der gesundheitsschädlichen grenze des alkaloidgehaltes von süsslupinen. Züchter 26:239–241. July/Aug. 1956.
22. ROBBINS, W., CRAFTS, A. C., and RAYNOR, R. N. Péridas causadas por las malas hierbas. Uruguay. Inst. Nac. de Colon. B. 7 (75/76):34–41. (Cont.) May/June 1956.
23. ROBERTS, H. A. Weed investigations. Natl. Veg. Res. Sta. Annu. Rpt. 6:56–57. 1956.
24. ROLAND, A. E. Weed control activities, Nova Scotia 1955. Canada. Natl. Weed Comt. East. Sect. Proc. 9:15–17. 1955, pub. 1956.
25. SAMMUELS, G., VIADE, H. C., and MARTORELL, L. F. Increased use of agriculture chemical in Puerto Rico. Sugar 51 (10):38, 40, 42. Oct. 1956.
26. SCHONBRUNNER, J., and PASCHER, O. Versuche zur chemischen bekämpfung des alpenampfers (Rumex alpinus L.). Pflanzenschutzberichte 17:33–43. Aug. 1956.
27. SOKOLOV, N. S. Chemical control of weeds in USA. (In Russian.) Zemledelie 4 (7):96–101. July 1956.
28. SOUTHERN WEED CONFERENCE. Proceedings, ninth annual meeting, January 16, 17, 18, 1956, New Orleans, Louisiana. n.p., 1956. 316 p.

29. SPILKER, W. E. What county agents expect. No. Cent. Weed Control Conf. Proc. 12:17–18. 1955.
30. STEEVES, I. D. Weed control activities in New Brunswick during 1955. Canada. Natl. Weed Comt. East. Sect. Proc. 9:11–13. 1955, pub. 1956.
31. STEPHEN, S. N. We need a weed now. Indian Farming 6 (3):18. June 1956.
32. STERLING, G. R. Brief weed report from Alberta. Canada. Natl. Weed Comt. West. Sect. Proc. 9:47–49. May 1956.
33. STOICHEV, O. Use of herbicides in the kolkhozes of Chernigovskaia Region. (In Russian.) Kolkhoz. Proizvodstvo 16 (5):39. May 1956.
34. TUPLIN, I. L. Prince Edward Island weed report 1955. Canada. Natl. Weed Comt. East. Sect. Proc. 9:14–15. 1955, pub. 1956.
35. VOROB'EV, F. K. Chemical control of weeds. (In Russian.) Zemledelie 4 (7):30–37. July 1956.
36. WATKINS, D. Weed control in New Zealand. Calif. Weed Conf. Proc. 8:22–30. 1956.
37. WILLARD, C. J. Goal No. 1: the weed-free farm. Pop. Mech. Mag. 106 (5): 165–168, 266, 270–272, 274. Nov. 1956.
38. WILLIAMSON, J. Algunas malezas dificiles de combatir en la Pampa. Rev. Argentina de Agron. 23:95–98. June 1956.
39. WOLFE, H. Weeds—where they come from and what they cost. Calif. Weed Conf. Proc. 8:10–17. 1956.
40. WOOD, H. E. Herbicides used agriculturally in western Canada for the control of weeds. Canada. Natl. Weed Comt. West. Sect. Proc. 9:43–44. May 1956.
41. ZALUSZER, H. Weed destruction is an urgent task. (In Hebrew.) Hassadeh 36:892–893. July 1956.

II. Botany of Weeds

A. Classification and Identification

42. HAWKES, J. G. A revision of the tuber-bearing Solanums. Roslin. Scot. Plant Breeding Sta. Annu Rpt. 1956:37–109. Ref.
43. THOMPSON, D. R., illus. Farm weeds; an aid to their recognition; colour plates reproduced from water-colours. Ed. 2. London, Shell Chem. Co., 1955. 80 p., illus.

B. Ecological Investigations & Surveys

44. AUERSCH, O. Unkräuter begünstigen das auftreten tierischer pflanzenschädlinge. Mitschurin Bewegung 5:506–509. June 1, 1956.
45. KORMANYNE, J. G. A gabonavetések és a burgonya gyomtársulásainak vizsgálata az Agrártudományi Egyetem Gödölloi Tangazdaságában [Untersuchung der unkrautassoziationen bei getreidesaaten und kartoffelsaaten in der lehrwirtschaft der Agrarwissenschaftlichen Universität in Gödöllo]. Budapest. Agrtudo. Egyetem. Agron. Kar. Kiadványai 2 (6), 25 p. Ref. 1955. German summary.
46. SHAKHOV, A. A. Michurinite principles of acclimatization of plants as an ecologo-physiological problem. (In Russian.) Agrobiologiia 3:95–106. Ref. May/June 1956.

C. Physiological Investigations

47. ABERG, B. On the effects of para-substitution in some plant growth regulators with phenyl nuclei. *In* Wain, R. L., and Wightman, F., ed. The chemistry and mode of action of plant growth substances, p. 93–116. Ref. New York, Acad. Press, 1956.
48. ADRIANI, M. J. Der wasserhaushalt der halophyten. Handb. der Pflanzenphysiol. 3:902–914. Ref. 1956.
49. AGAFONOVA, A. F. The effect of boron in soil liming on the chemical composition of plants. (In Russian.) Vsesoiuzn. Nauch. Issled. Inst. Udobr. Agrotekh. i Agropochvoved. Trudy 31:331–347. Ref. 1955.

50. ANDREN, F. Chloric acid injuries in connection with vine killing. (In Swedish.) Sweden. Stat. Växtskyddsanst. Växtskyddsnot. 1/2:30–31. Apr. 1956.
51. AUDUS, L. J., and THRESH, R. The effects of synthetic growth-regulator treatments on the levels of free endogenous growth-substances in plants. Ann. Bot. (n.s.) 20:439–459. Ref. July 1956.
52. AUDUS, L. J., and THRESH, R. The effects of synthetic growth substances in the level of endogenous auxins in plants. *In* Wain, R. L., and Wightman, F., ed. The chemistry and mode of action of plant growth substances, p. 248–252. Ref. New York, Acad. Press, 1956.
53. BARTON, L. V., and MACNAB, J. Relation of different gases to the soaking injury of seeds. III. Some chemical aspects. (Abs.) Plant Physiol. 31 (sup.):xv. 1956.
54. BENNET-CLARK, T. A. The kinetics of auxin-induced growth. *In* Wain, R. L., and Wightman, F., ed. The chemistry and mode of action of plant growth substances, p. 310–312. New York, Acad. Press, 1956.
55. BENNET-CLARK, T. A. Salt accumulation and mode of action of auxin. *In* Wain, R. L., and Wightman, F., ed. The chemistry and mode of action of plant growth substances, p. 284–291. New York, Acad. Press, 1956.
56. BENTLEY, J. A., HOUSLEY, S., and BRITTON, G. Hormones and hormone precursors in leaves, roots, and seeds. *In* Wain, R. L., and Wightman, F., ed. The chemistry and mode of action of plant growth substances, p. 40–51. Ref. New York, Acad. Press, 1956.
57. BHARDWAJ, S. N., and RAO, I. M. Influence of time of sowing on the effect of 2,4–D on growth and maturity of wheat. Physiol. Plant. 9:257–264. 1956.
58. BONNER, J., and FOSTER, R. J. The kinetics of auxin-induced growth. *In* Wain, R. L., and Wightman, F., ed. The chemistry and mode of action of plant growth substances, p. 295–309. Ref. New York, Acad. Press, 1956.
59. BONNER, J., ORDIN, L., and CLELAND, R. Auxin-induced water uptake. *In* Wain, R. L., and Wightman, F., ed. The chemistry and mode of action of plant growth substances, p. 260–270. Ref. New York, Acad. Press, 1956.
60. BURSTROM, H. Die bedeutung des wasserzustandes für das wachstum. Handb. der Pflanzenphysiol. 3:665–668. Ref. 1956.
61. BURSTROM, H., and HANSEN, B. A. M. The mode of growth action on some naphthoxy compounds. *In* Wain, R. L., and Wightman, F., ed. The chemistry and mode of action of plant growth substances, p. 134–140. Ref. New York, Acad. Press, 1956.
62. BURTON, W. G. Suppression of the sprouting of potatoes by the vapour of alcohols. Nature [London] 178–218. July 28, 1956.
63. CARTWRIGHT, P. M., SYKES, J. T., and WAIN, R. L. The distribution of natural hormones in germinating seeds and seedling plants. *In* Wain, R. L., and Wightman, F., ed. The chemistry and mode of action of plant growth substances, p. 32–39. New York, Acad. Press, 1956.
64. CHASSON, R., and LEVITT, J. Stimulation of calcium uptake by potato tuber in response to 2,4–dinitrophenol. (Abs.) Plant Physiol. 31 (sup.): vi. 1956.
65. DATTA, S. C., and DUNN, S. The action of 2,4–D on mustard as modified by six different light qualities. (Abs.) Plant Physiol. 31 (sup.):xxii. 1956.
66. DAVISON, R. M. Effect of various growth-regulating substances on fruit drop and storage life of apples. New Zeal. J. Sci. & Technol. A, Agr. Res. Sect. 38:45–51. Ref. June 1956.
67. ELIASSON, L., and MATHIESEN, I. The effect of 2,4–dinitrophenol and some oxidase inhibitors on the oxygen uptake in different parts of wheat roots. Physiol. Plant. 9:265–279. Ref. 1956.
68. ENNIS, W. B. Responses of corn to 3–amino–1,2,4–triazole. South. Weed Conf. Proc. 9:71–79. 1956.
69. FALUDI, B. Die wirkung von 2–4–dichlorophenoxyessigsäure und glutathion auf das wachstum der gewebekulturen von kartoffeln. Naturwissenschaften 43:280–281. June 15, 1956.

70. FLETCHER, W. W., and RAYMOND, J. C. Toxicity and breakdown of 'hormone' herbicides. Nature [London] 178:151–152. July 21, 1956. Effects on white clover.
71. FREDGA, A. Zur kenntnis der sterischen spezifität pflanzlicher wuchsstoffe. Chem. Ber. 89:322–327. 1956.
72. GALSTON, A. W. Some metabolic consequences of the administration of indoleacetic acid to plant cells. *In* Wain, R. L., and Wightman, F., ed. The chemistry and mode of action of plant growth substances, p. 219–233. Ref. New York, Acad. Press, 1956.
73. GORDON, S. A. The biogenesis of natural auxins. *In* Wain, R. L., and Wightman, F., ed. The chemistry and mode of action of plant growth substances, p. 65–75. Ref. New York, Acad. Press, 1956.
74. GOWING, D. P. An hypothesis of the role of naphthaleneacetic acid in flower induction in the pineapple. Amer. J. Bot. 43:411–418. Ref. June 1956.
75. GRAY, R. A., and HENDLIN, D. Inhibition of growth and chlorophyll formation in plants by O-methyl threonine. (Abs.) Plant Physiol. 31 (sup.): xxi. 1956.
76. HELGESON, E. A. Quackgrass root extract has puzzling effect on seeds of crop plants. N. Dak. Agr. Expt. Sta. Bimon. B, 18:191–192. July/Aug. 1956.
77. HENDERSON, J. H. M. The influence of 2,4-D and other growth regulators on phototropism. (Abs.) Plant Physiol. 31 (sup.):xiv. 1956.
78. HILLMAN, W. S., and GALSTON, A. W. A photoinduced increase of an IAA oxidase inhibitor in etiolated peas. (Abs.) Plant Physiol. 31 (sup.):xiii. 1956.
79. HOFFMAN, M. B. Thinning apples and peaches by the use of chemical sprays. State Hort. Assoc. Pa. Proc. 1956:59–63, 65–66.
80. HULL, H. M. Chemical and physiological studies. Calif. Weed Conf. Proc. 8:57–59. 1956.
81. HUMPHREYS, T. E., and DUGGER, W. M. The effect of 2,4-dichlorophenoxyacetic acid on the respiration of etiolated pea seedlings. (Abs.) Plant Physiol. 31 (sup.):xxii. 1956.
82. JOHNSON, M. K., MAGEE, L. A., and COLMER, A. R. Some factors affecting the respiratory response of Azotobacter to 2,4-D and related compounds. South. Weed Conf. Proc. 9:152. 1956.
83. JOHNSON, M. P., and BONNER, J. The uptake of auxin by plant tissue. Physiol. Plant. 9:102–118. Ref. 1956.
84. JOHNSON, S. P., and COWLEY, W. R. A preliminary study of the effect of low concentrations of phenoxytype growth regulators on early physiological shedding in Deltapine D10, TPSA, cotton. I. Seed treatment with dusts. Agron. J. 48:412–415. Sept. 1956.
85. KAINDL, K. The action-concentration curves of mixtures of growth-promoting and growth-inhibiting substances. *In* Wain, R. L., and Wightman, F., ed. The chemistry and mode of action of plant growth substances, p. 159–164. New York, Acad. Press, 1956.
86. KONONKOV, P. F. Effect of place of seed reproduction on peculiarities of the light phase in sorrel [Rumex]. (In Russian.) Agrobiologiia 3:128–129. May/June 1956.
87. LANG, A. Induction of flower formation in biennial Hyoscyamus by treatment with gibberellin. Naturwissenschaften 43:284–285. June 15, 1956.
88. LARSEN, P. Geotropic responses in roots. Some theoretical and technical problems. *In* Wain, R. L., and Wightman, F., ed. The chemistry and mode of action of plant growth substances, p. 76–90. Ref. New York, Acad. Press, 1956.
89. LEONARD, O. A. Effect of additives on the herbicidal effectiveness of 2,4-dichlorophenoxyacetic acid. (Abs.) Plant Physiol. 31 (sup.):xxi–xxii. 1956.
90. LEOPOLD, A. C., and PRICE, C. A. The influence of growth substances upon sulphydryl compounds. *In* Wain, R. L., and Wightman, F., ed. The chemistry and mode of action of plant growth substances, p. 271–283. Ref. New York, Acad. Press, 1956.

91. LINDER, P. J., and CRAIG, J. C. The rate of movement of tagged alpha-methoxyphenylacetic acid out of roots. (Abs.) Plant Physiol. 31 (sup.): xlii–xliii. 1956.
92. LINSER, H. Chemical configuration and action of different growth substances and growth inhibitors. *In* Wain, R. L., and Wightman, F., ed. The chemistry and mode of action of plant growth substances, p. 141–158. Ref. New York, Acad. Press, 1956.
93. LOCKHART, J. A. The effect of light and the gibberellins on stem elongation in dwarf and normal pea seedlings. (Abs.) Plant Physiol. 31 (sup.): xii. 1956.
94. LUCKWILL, L. C., and WOODCOCK, D. Relationship of molecular structure of some naphthyloxy compounds and their biological activity as plant growth regulating substances. *In* Wain, R. L., and Wightman, F., ed. The chemistry and mode of action of plant growth substances, p. 195–204. Ref. New York, Acad. Press, 1956.
95. MARTH, P. C., AUDIA, W. V., and MITCHELL, J. W. Effect of gibberellic acid on growth and development of various species of plants. (Abs.) Plant Physiol. 31 (sup.):xliii. 1956.
96. MUZIK, T. J., MORRIS, M. P., and CRUZADO, H. J. Translocation and metabolism of 3-(p-chlorophenyl)-1, 1-dimethyl urea [CMU] in velvetbeans. (Abs.) Plant Physiol. 31 (sup.):xlii. 1956.
97. NITSCH, J. P. Methods for the investigation of natural auxins and growth inhibitors. *In* Wain, R. L., and Wightman, F., ed. The chemistry and mode of action of plant growth substances, p. 3–31. Ref. New York, Acad. Press, 1956.
98. ORGELL, W. H., and WEINTRAUB, R. L. Some principles involved in foliar absorption of 2,4-D. (Abs.) Plant Physiol. 31 (sup.)xxi. 1956.
99. OVERBEEK, J. VAN. Studies on the relation between molecular structure and penetration of growth regulators into plants. *In* Wain, R. L., and Wightman, F., ed. The chemistry and mode of action of plant growth substances, p. 205–210. New York, Acad. Press, 1956.
100. PFIRSCH, E. Activité auxinique et rapports auxine/inhibiteur dans les plantules de Sinapis alba L. Soc. Bot. de France. B. 103:132–137. Mar./Apr. 1956.
101. PILET, P. E. Emploi de l'hydrazide maléique (1,2-dihydropyridazine-3,6-dione) en physiologie végétale. Phyton [Horn] 6:275–305. Ref. June 15, 1956.
102. RAMSHORN, K. Uber eine modifikative fruchtformänderung nach einmaliger 2,4-D-applikation bei Lycopersicon esculentum. Naturwissenschaften 43:230. May 15, 1956.
103. ROGERS, B. J. Action of 3-amino-1,2,4-triazole in plants. (Abs.) Plant Physiol. 31 (sup.):xxi. 1956.
104. ROHRBAUGH, L. M., and RICE, E. L. Relation of potassium deficiency to the movement of 2,4-D in tomato plants. (Abs.) Plant Physiol. 31 (sup.): xvi.
105. SEELEY, R. C., and others. Chromatographic investigations on the metabolism of certain indole derivatives in plant tissues. *In* Wain, R. L., and Wightman, F., ed. The chemistry and mode of action of plant growth substances, p. 234–247. New York, Acad. Press, 1956.
106. SHINHARA, K., NAKAMURA, H., and KUBO, K. On the measures of failure in ripening of rape plants. (In Japanese.) Kyushu Agr. Res. 17:135–136. May 1956.
107. SKINNER, J. C. The effect of maleic hydrazide on the sucrose content of sugar cane. Queensland. Bur. Sugar Expt. Sta. Tech. Commun. 1, 11 p. Ref. 1956.
108. SMIRNOV, B. M. On the period of dormancy in rhizomic weeds. (In Russian.) Agrobiologiia 3:137–139. May/June 1956.
109. STEWARD, F. C., and SHANTZ, E. M. The chemical induction of growth in plant tissue cultures. *In* Wain, R. L., and Wightman, F., ed. The chemistry and mode of action of plant growth substances, p. 165–186. Ref. New York, Acad. Press, 1956.

110. STEWARD, F. C., and others. The induction of growth in potato tissue: substances which act synergistically with coconut milk. (Abs.) Plant Physiol. 31 (sup.):xxxviii–xxxix. 1956.
111. STORZ, H. Was nach der bekämpfung von unhölzern mit wuchsstoffmitteln auf weideland zu machen ist! Gesunde Pflanzen 8:113–114, 116–117. June 1956.
112. SWANSON, C. R., and others. Effect of 2,4–dichlorophenoxyacetic acid and other growth-regulators on the formation of a red pigment in Jerusalem artichoke tuber tissue. Plant Physiol. 31:315–316. July 1956.
113. TAMURA, J. Effect of maleic hydrazide on the flowering of Chrysanthemum morifolium. Osaka. U. B. Ser. B, Agr. & Biol. 5:27–36. Ref. 1955.
114. WAIN, R. L., and WIGHTMAN, F., ed. The chemistry and mode of action of plant growth substances; proceedings of a symposium held at Wye College, University of London, July 1955. New York, Acad. Press, 1956. 312 p. Ref.
115. WEST, C., and PHINNEY, B. O. Properties of gibberellin-like factors from extracts of higher plants. (Abs.) Plant Physiol. 31 (sup.):xx. 1956.
116. WOODS, F. W. Relation of soil moisture and temperature to weed control. South. Weed Conf. Proc. 9:161–165. 1956.
117. YOSHIMURA, K., and FURUTA, K. Inhibition of carrot bolting with MH 30. (In Japanese.) Kyushu Agr. Res. 17:83–84. May 1956.
118. ZUKEL, J. W., and others. Effect of some factors on rate of absorption of maleic hydrazide. (Abs.) Plant Physiol. 31 (sup.):xxi. 1956.

D. Morphological and Anatomical Investigations

119. BUXBAUM, F. Das gesetz der verkürzung der vegetativen phase in der familie der Cactaceae. Osterr. Bot. Z. 103:353–362. Ref. 1956.
120. FROMANTIN, J. Quelques considérations d'ordre évolutif à la suite des effets du 2,4–D sur la structure des carpelles de Ranunculus arvensis L. Rev. Gén. de Bot. 63:293–313. Ref. July 1956.
121. MAGIN, T. L'ontogénie du collenchyme chez Lamium album L. Rev. de Cytol. et de Biol. Vég. 17:219–258. Ref. 1956.
122. ROTINI, O. T., and MARINO, G. The antimitotic action of cyanates on bulbs of Allium cepa L. (In Italian.) Ricerca Sci. 26:2139–2145. July 1956.
123. STEVENS, O. A. Flowering dates of weeds in North Dakota. N. Dak. Agr. Expt. Sta. Bimon. B. 18:209–213. July/Aug. 1956.
124. THODAY, D. Modes of union and interaction between parasite and host in the Loranthaceae. I. Viscoideae, not including Phoradendreae. Roy. Soc. London. Proc. Ser. B, Biol. Sci. 145:531–548. Ref. Aug. 28, 1956.
125. WASSBERG, C., and GOODRICH, F. J. A study of the anatomical effects produced in the leaves of Datura stramonium L. by the action of 2,4–dichlorophenoxyacetic acid. Amer. Pharm. Assoc. J. Sci. Ed. 45:495–497. Ref. July 1956.
126. WILSON, S. M., DANIEL, A., and WILSON, G. B. Cytological and genetical effects of the defoliant Endothal. J. Hered. 47:151–155. July/Aug. 1956.

E. Weed Seed Investigations

127. ANDERSON, E. G. Negotiations re the Seeds Act. Canada. Natl. Weed Comt. West. Sect. Proc. 9:28–32. May 1956.
128. BECK, T. V. Canadian seed grain surveys. No. Cent. Weed Control Conf. Proc. 12:13–14. 1955.
129. KLEIN, W. Untersuchungen zur bestimmung des keimungsminimums landwirtschaftlicher unkräuter. Z. f. Acker- u. Pflanzenbau. 101:395–430. Ref. June 1956.
130. MACRAE, J. W. What can be done about the weed seed content in seed and feed supplies. Canada. Natl. Weed Comt. East. Sect. Proc. 9:46–51. 1955, pub. 1956.
131. METHOT, P. What can be done about the weed seed content in seed and feed supplies. Canada. Natl. Weed Comt. East. Sect. Proc. 9:52–53. 1955, pub. 1956.
132. PENNSYLVANIA. BUR. OF PLANT INDUSTRY. Seed analyses report—1955. Pa. Dept. Agr. B. 39 (2), 18 p. Mar./Apr. 1956.

III. WEED CONTROL

A. Cultural

133. GREEN, K. R. Weed control by management. (Sum.) Agr. Bur. N.S. Wales. State Conf. Hawkesbury Agr. Col. 32:8–10. 1956.
134. KAWAMATA, M., and TSUKIJIMA, Y. Killing effect of soil covering upon Syntherisma Dulac. var. ciliaris Honda. (In Japanese.) Kyushu Agr. Res. 17:61. May 1956.
135. MILIAVSKIĬ, I. O. Weed control—the most important condition for obtaining high yields. (In Russian.) Sovkhoz. Proizvodstvo 3:20–23. Mar. 1955.
136. RECHENTHIN, C. A. Rooting, chopping control brush. Amer. Cattle Prod. 38 (5):9–11. Oct. 1956.
137. SMITH, K. O. Cultivation and special mechanical means. Calif. Weed Conf. Proc. 8:138–139. 1956.

B. Chemical

1. *Weeds in field crops*

138. ALBERT, W. B. Tolerance of peanuts to various pre-emergence herbicides. South. Weed Conf. Proc. 9:36–39. 1956.
139. ALBERT, W. B., and others. Weed control and cotton plant tolerance to various pre-emergence herbicides. South. Weed Conf. Proc. 9:10–14. 1956.
140. ARAI, M., KAWASHIMA, R., and KUMAZAKI, Y. Studies on weed control in rice culture by 2,4–dichlorophenoxyacetic acid. V–VI. (In Japanese.) Kanto-Tosan Agr. Expt. Sta. J. 7:1–24. Ref. May 1955.
141. BEREZOVSKIĬ, M. Chemical dusting of crops. (In Russian.) Kolkhoz. Proizvodstvo 16 (5):38. May 1956.
142. BURT, E. O. Chemical weed control in oats. South. Weed Conf. Proc. 9:80–85. 1956.
143. BURT, E. O. Herbicides in soybeans. South. Weed Conf. Proc. 9:61–64. 1956.
144. BURT, E. O. Pre- and post-emergence herbicides in corn. South. Weed Conf. Proc. 9:65–70. 1956.
145. BURT, E. O. Pre- and post-emergence herbicides in peanuts. South. Weed Conf. Proc. 9:40–47. 1956.
146. CARNS, H., and GOODMAN, V. H. Responses of cotton to 2,4–D. Miss. Agr. Expt. Sta. B. 541, 15 p. Apr. 1956.
147. CHAPPELL, W. E. Screening tests on peanuts, soybeans and castor beans in 1955. South. Weed Conf. Proc. 9:57–60. 1956.
148. CHAPPELL, W. E. Some effects of pre- and post-emergence herbicide treatments on peanuts. South. Weed Conf. Proc. 9:48–53. 1956.
149. CHAPPELL, W. E., and DUKE, G. B. The effects of rollers and depth of planting on peanuts and weeds sprayed with 2,4–dichlorophenoxyethyl sulphate. South. Weed Conf. Proc. 9:54–56. 1956.
150. FOY, C. L., and MILLER, J. H. Weed control in California cotton. Calif. Weed Conf. Proc. 8:100–104. 1956.
151. FRANS, R. E., DAVIS, A. M., and HINKLE, D. A. Chemical weed control in cotton, soybeans, and corn, 1952–1955. Ark. Agr. Expt. Sta. Rpt. Ser. 55, 22 p. June 1956.
152. FURTICK, W. R. Perennial herbaceous weeds. Calif. Weed Conf. Proc. 8:48. 1956.
153. GRANSTROM, B. Weed control in spring sown crops. (In Swedish.) Sweden. Stat. Jordbrförsök.Meddel. 65/70:5–17. 1956.
154. GUZMAN, V. L. Suggested methods for controlling weeds in sugar cane on organic soil. Fla. Everglades Expt. Sta. Mimeo. Rpt. 56–16; 3 p. June 5, 1956.
155. GUZMAN, V. L., and WOLF, E. A. Pre-emergence weeding of sweet corn with TCB in organic soils. South. Weed Conf. Proc. 9:171–174. 1956.
156. HEATH, R. Local problems of weed control in sugar beets. Calif. Weed Conf. Proc. 8:112–114. 1956.

157. LEE, W. O. Control of annual weeds in cereal and forage crops. Calif. Weed Conf. Proc. 8:53–56. 1956.
158. LOUPE, D. T. Extension aspects of weed and grass control in sugarcane in Louisiana. South. Weed Conf. Proc. 9:237–241. 1956.
159. MCWHORTER, C. G., WOOTEN, O. B., and CROWE, G. B. An economic evaluation of various weed control practices in the Delta area of Mississippi. South. Weed Conf. Proc. 9:19–31. 1956.
160. MANN, R. A., and HAMILTON, R. D. Herbicidal field studies. South. Weed Conf. Proc. 9:146–149. 1956.
161. MAUPAS, A. Sur le désherbage chimique des cultures de maïs déjà levées; (traitements dits de "post-emergence.") Agriculture [Paris] 19:177–178. June 1956.
162. MILLER, J. H., and FOY, C. L. Survey of weed problems associated with California cotton production. South. Weed Conf. Proc. 9:32–35. 1956.
163. NORTH CAROLINA. UNIVERSITY. STATE COLLEGE OF AGRICULTURE AND ENGINEERING. EXTENSION SERV. Weed control in cotton, 1956. Raleigh, 1956. 8 p.
164. ORCHARD, H. E. Safer crop spraying for weed control. So. Austral. Dept. Agr. J. 59:458–462, 465. June 1956.
165. PORTER, W. K., and others. Chemical weed control in cotton. Tenn. Agr. Expt. Sta. C. 42, 8 p. Feb. 1956.
166. PRUGALOV, A. From the practices of herbicide utilization on cotton plantations in USA. (In Russian.) Khlopkovodstvo 6 (8):57–59. Aug. 1956.
167. REA, H. E. Controlling established Johnson grass in cotton and other row crops. South. Weed Conf. Proc. 9:15–18. 1956.
168. RIDDLE, O. C. Alfalfa weed control problems of the Sacramento Delta. Calif. Weed Conf. Proc. 8:107–109. 1956.
169. ROBINSON, R. G. Weed research and your corn crop. Amer. Seed Trade Assoc. Year Book & Proc. 72:232–233. 1955.
170. STAMPER, E. R. Recommendations for the control of Johnson grass [Sorghum halepense] and other weeds in sugarcane. Sugar J. 19 (2):35–36. July 1956.
171. STAMPER, E. R. Weed and grass control in sugarcane in Louisiana. South. Weed Conf. Proc. 9:86–91. 1956.
172. STANDIFER, L. C., and ENNIS, W. B. Developmental studies on sodium 2,2–dichloropropionate as an herbicide for Johnson grass. South. Weed Conf. Proc. 9:183–189. 1956.
173. STANIFORTH, D. W., and WEBER, C. R. Competition in variable weed and soybean stands. Agron. Abs. 1956:94.
174. STANIFORTH, D. W., and WEBER, C. R. Effects of annual weeds on the growth and yield of soybeans. Agron. J. 48:467–471. Oct. 1956.
175. STEWARD, E. Control of weeds in plant cane by chemical spray. So. African Sugar J. 40:429, 431, 433. June 1956.
176. THOMPSON, J. T., HAUSER, E. W., and DEMPSEY, A. H. The effect of several herbicides on transplanted sweet potatoes. South. Weed Conf. Proc. 9:179–182. 1956.
177. TODD, F. A., and CLAYTON, E. E. Chemical treatments for the control of weeds and diseases in tobacco plant beds. N. C. Agr. Expt. Sta. Tech. B. 119, 23 p. Mar. 1956.
178. TODD, F. A., and LUCAS, G. B. Treatment of tobacco plant bed soils with methyl bromide. N. C. Agr. Expt. Sta. B. 399, 20 p. Ref. May 1956.
179. VOROB'EV, F. K., SKVORTSOVA, L. A., and KONSTANTINOVA, A. I. Utilization of 2,4–D in weed control under conditions of [wheat] irrigation. (In Russian.) Moskov. Ordena Lenina Sel'skokhoz. Akad. im. K. A. Timiriazeva. Dok. 22:372–379. 1956.
180. WAYWELL, C. G. The effect of herbicidal treatments on oats. Canada. Natl. Weed Comt. East. Sect. Proc. 9:109–117. 1955, pub. 1956.
181. WAYWELL, C. G. Results of herbicidal treatments on onion plots. Canada. Natl. Weed Comt. East. Sect. Proc. 9:107–108. 1955, pub. 1956.
182. WIDDIFIELD, R. B., and HELGESON, E. A. Chemical weed control in North Dakota field crops. N. Dak. Agr. Col. Ext. C. A–253, 6 p.-folder. Apr. 1956.

183. WILLIAMS, H. Weed control problems in rice. Calif. Weed Conf. Proc. 8:110–112. 1956.
184. WILLIAMS, R. E. Weeds in rice. VIII. Rice J. 59 (8):22–23. July 1956.
185. WILLIAMS, R. E. Weeds in rice. IX. Rice J. 59 (9):15. Aug. 1956.
186. WILLIAMS, R. E. Weeds in rice. X. Rice J. 59 (10):16–17. Sept. 1956.
187. WOOTEN, O. B., and MCWHORTER, C. G. Progress report on weed control in cotton in the humid areas. (Abs.) Assoc. South. Agr. Workers. Proc. 53:40–41. 1956.

2. *Weeds in horticultural, ornamental and vegetable crops*

188. BECKER, A. Unkrautbekämpfung und obstkulturen. Obstbauversring. des Alten Landes. Mitt. 11:133–135. May 1956.
189. FEDERACIÓN NACIONAL DE CAFETEROS DE COLOMBIA. CAMPAÑA DE DEFENSA Y RESTAURACIÓN DE SUELOS. Desyerbe selectivamente su cafetal y defienda el suelo. Ed. 3. Chinchina, Colombia, 1955. 16 p.
190. FISHER, J. R. Weed control in grapes. Calif. Weed Conf. Proc. 8:106–107. 1956.
191. GRAAF, A. J. V. D. Chemical control of weeds in peony beds. (In Dutch.) Boskoop. Ver. Proefsta. v. de Boomkwekerij. Jaarb. 1955:108–109.
192. GUZMAN, V. L. Suggested methods for control of weeds in some vegetable crops growing on organic soils. Fla. Everglades Expt. Sta. Mimeo. Rpt. 56–13, 4 p. May 17, 1956.
193. GUZMAN, V. L. Weed control in carrots with CIPC on organic soil. South. Weed Conf. Proc. 9:175–178. 1956.
194. LAUMEISTER, L. T. Weed control in vegetable crops. Calif. Weed Conf. Proc. 8:98–99. 1956.
195. LEEFE, J. S. Chemical weed control in orchards. Nova Scotia Fruit Growers' Assoc. Annu. Rpt. 92:125–126. Dec. 1955.
196. LEHMANN-BECKOW, W. Chemische unkrautbekämpfung im gartenbau. Deut. Gartbau. 3:130–132. May 1956.
197. LINT, H. VAN. Chemical control of weeds in conifer seedling beds. (In Dutch.) Boskoop. Ver. Proefsta. v. de Boomkwekerij. Jaarb. 1955:112–114.
198. LINT, H. VAN. Demonstrations of chemical weed control. (In Dutch.) Boskoop. Ver. Proefsta. v. de Boomkwekerij. Jaarb. 1955:114.
199. MELVILLE, G., PERKINS, D., and STAMPER, R. The effect of several chemicals at various rates on horticultural crops for weed and grass control in Louisiana. South. Weed Conf. Proc. 9:167–170. 1956.
200. MILLET, J. A. P. To weed or not to weed or the psychoanalyst's dilemma. Pop. Gard. [New York] 7 (9):54–55, 72. Sept. 1956.
201. ROBERTS, H. A. A comparison of pentachlorophenol and sulphuric acid for pre-emergence weed control in onions. Natl. Veg. Res. Sta. Annu. Rpt. 6:58–60. 1956.
202. ROBINSON, J. B. D. Recent results of experiments with weedkillers in coffee. Coffee Bd. Kenya Mon. B. 21:249–251, 254. Sept. 1956.
203. SAMARIN, P. I. Experiment in controlling weeds [on vegetable plots]. (In Russian.) Sad i Ogorod 7:15–18. July 1956.
204. SCHODEL, H. Helft den jungwaldungen gegen die unkräuter! DLZ—Deut. Landtech. Z. 7:260–261. Aug. 1956.
205. SOSTER, P. Experiments with chemical herbicides in forest nurseries. (In Italian.) Monti e Boschi 7:303–316. July 1956.
206. WARREN, G. F. Weed control for direct-seeded tomatoes and plant fields. Food Packer 37 (8):30. Aug. 1956.
207. WITTIG, G. Wie ist eine wirtschaftliche unkrautbekämpfung im gemüsebau durchzuführen? Mitschurin Bewegung 5:447–450. May 15, 1956.

3. *Weeds in grasslands (pastures, etc.)*

208. FOLKNER, J. S. Maleic hydrazide, an aid in summer-winter turf transition. Golf Course Rpt. 24 (6):5–7. Aug. 1956.
209. IURKEVICH, I. D., and SMOLIAK, L. A. Use of herbicides for the clearing of pastures and meadows from brush. (In Russian.) Zhivotnovodstvo 5:71–74. May 1956.

210. JANSEN, L. L. Herbaceous range weeds. Calif. Weed Conf. Proc. 8:52–53. 1956.
211. MASERA, M. Pasture improvement: the destruction of bushes. (In Italian.) Rass. Econ. della Prov. di Sondrio 9 (5):9–11. May 1956.
212. OSTERLI, V. P. Weed control in irrigated pastures. Calif. Weed Conf. Proc. 8:114–115. 1956.
213. ROBERTS, E. C., and HAVIS, J. R. Lawn pests. Mass. U. Agr. Ext. L. 294, 12 p. Apr. 1956.
214. SHUH, J. E. Pasture improvement through weed control—Nova Scotia. Canada. Natl. Weed Comt. East. Sect. Proc. 9:42–43. 1955, pub. 1956.
215. STEEVES, I. D. Pasture improvement through weed control. Canada. Natl. Weed Comt. East. Sect. Proc. 9:43–45. 1955, pub. 1956.
216. SYMPOSIUM—pasture improvement through weed control. Canada. Natl. Weed Comt. East. Sect. Proc. 9:29–45. 1955, pub. 1956.
217. THOMAS, N. J. Pasture improvement through weed control—Ontario. Canada. Weed Comt. East. Sect. Proc. 9:30–39. 1955, pub. 1956.
218. TUPLIN, I. L. Pasture improvement through weed control, Prince Edward Island. Canada. Natl. Weed Comt. East. Sect. Proc. 9:39–41. 1955, pub. 1956.

4. *Weeds in specialized areas, (ditches, etc.)*

219. FUDGE, O. L. Irrigation problems and costs. Calif. Weed Conf. Proc. 8:90–93. 1956.
220. JACOBS, H. Highway weed and brush control. Pub. Works 87 (9):126–128. Sept. 1956.
221. LINT, H. VAN. Chemical control of weeds between shrubs, avenue trees and conifers on sandy soil. (In Dutch.) Boskoop. Ver. Proefsta. v. de Boomkwekerij. Jaarb. 1955:109–111.
222. MCCAMBRIDGE, J. R. Chlorea for industrial and rights-of-way weed control and sodium arsenite for aquatic weed control. Calif. Weed. Conf. Proc. 8:63–69. 1956.
223. MCCAMBRIDGE, J. R. Vegetation control on rights-of-way and industrial sites. Calif. Weed Conf. Proc. 8:59–61. 1956.
224. SKRDLA, W. Herbicides for controlling weeds in drainage ditches and other areas. Agron. Abs. 1956:102.
225. WOOZLEY, E. Weed control and the Bureau of Land Management. Calif. Weed Conf. Proc. 8:17–21. 1956.
226. ZELAND, M. G., and ZAGORSKII, I. M. The control of the woody-brushwood vegetation on reclamation canals by the use of chemical means. (In Russian.) Gidrotekh. i Melior. 8 (4):28–34. Apr. 1956.

5. *Woody plants*

227. BYLTERUD, A. Chemicals against brush and weeds. (In Norwegian.) Norsk Skogbruk 2:333–336. May 1956.
228. CARVELL, K. L. The use of chemicals in controlling forest stand composition in the Duke Forest [North Carolina]. J. Forestry 54:525–530. Aug. 1956.
229. ELWELL, H. M., ELDER, W. C., and LARSON, R. E. Recent results on control of oak with aerial applications of herbicides in Oklahoma. South. Weed Conf. Proc. 9:113–117. 1956.
230. GODDARD, R. E. Basal spray treatments of small hardwoods with chemical herbicide 2,4,5–T. Tex. Forest Serv. Res. Note 13, 20 p. July 1955.
231. GRAAF, A. J. V. D. Chemical control of big weeds. (In Dutch.) Boskoop. Ver. Proefsta. v. de Boomkwekerij. Jaarb. 1955:108.
232. HARVEY, W. A. Our new frontiers. Calif. Weed Conf. Proc. 8:156–158. 1956.
233. LEONARD, O. A. Control of woody plants with chemicals in combination with other methods. Calif. Weed Conf. Proc. 8:93–98. 1956.
234. LOPEZ CADENAS DEL LLANO, F. Métodos químicos de control de matorral. Montes 12:125–128. Mar./Apr. 1956.

235. McCULLY, W. G., and DARROW, R. A. Aerial and broadcast applications of granular Karmex in oak woodlands. South. Weed Conf. Proc. 9:118–120. 1956.
236. REYNOLDS, R. R. Upland hardwoods in south Arkansas pine stands—aerial or underground fifth column? J. Forestry 54:585–586. Sept. 1956.
237. SAMPSON, A. W. Lucha contra el matorral y los arboles inutiles. Tierra [México] 11:777, 817–820. Sept. 1956.
238. SHREWSBURY, C. L. Effective brush control. Soil & Water Mag. 5 (8):26–27. Aug. 1956.
239. SILKER, T. H., and DARROW, R. A. Aerial applications of 2,4,5–T and Silvex for hardwood control and increased forage production in scrub-hardwood—pine stands in east Texas. South. Weed Conf. Proc. 9:130–133. 1956.
240. SUGGITT, J. W. Brush control acreage sprayed in Canada—1954. Canada. Natl. Weed Comt. East. Sect. Proc. 9:103–106. Ref. 1955, pub. 1956.
241. TROMP, P. H. M. Thinning and control of brush in young stands. (In Dutch.) Nederland. Heidemaatsch. Tijdschr. 67:188–191. July/Aug. 1956.
242. TSCHIRLEY, F. H. Woody plant control in the Western States. Calif. Weed Conf. Proc. 8:49–52. 1956.
243. WALKER, A. H. Brush control methods in Texas. South. Weed Conf. Proc. 9:92–94. 1956.
244. WALKER, L. C. Studies of chlorobenzoic acid, a progress report. South. Weed Conf. Proc. 9:134–141. Ref. 1956.
245. WIDDIFIELD, R. B., and HELGESON, E. A. Chemical control of brush and shrubs. N. Dak. Agr. Col. Ext. C. A–255, 4 p. May 1956.

6. *Aquatic weeds*

246. REED, L. R. 1955 field experiences with sodium arsenite for aquatic weed control. South. Weed Conf. Proc. 9:245–249. 1956.
247. ARLE, H. F. Aquatic weeds: submersed and emergent. Calif. Weed Conf. Proc. 8:56–57. 1956.
248. GESSNER, F. Hydrobotanik, die physiologischen grundlagen der pflanzenverbreitung im wasser. I. Energiehaushalt. Hochschb. f. Biol. 3, 517 p. Ref. 1955.
249. HARRISON, D. S. Control of "head wool" in ditches. Fla. Everglades Expt. Sta. Mimeo Rpt. 56–11, 1 p. May 17, 1956.
250. MARINOVIC, R. Z. Contribution à l'étude des algues des eaux stagnantes et des eaux courantes aux environs de Belgrade. (In Serbo-Croatian.) Prirodnjacki Muz. Srpske Zeml. Glasnik. Ser. B, Biol. Nauk. 7:83–122. 1955.

7. *Specific weeds*

251. ÅBERG, E. We have too much wild oats. (In Swedish.) Lantmannen 40: 571–573. June 23, 1956.
252. ARMONI, S., and others. Control of Bermuda grass [Cynodon dactylon] in irrigated areas. (In Hebrew.) Hassadeh 36:847–848. (Concl.) July 1956.
253. ARMONI, S., and others. Destruction of Bermuda grass in irrigated areas. (In Hebrew.) Hassadeh 36:750–752. (Cont.) June 1956.
254. ARTEAGA, P. H. Estramonio (Datura stramonium L.) Café de El Salvador 26:145–146. Mar./Apr. 1956.
255. BECKER, A. Zur herbstzeitlosenbekämpfung. Gesunde Pflanzen 8:154–155. Aug. 1956.
256. BEHRENS, R., FISHER, C. E., and MEADORS, C. H. Response of mesquite seedlings to 2,4,5–T as influenced by droplet size and spray volume. South. Weed Conf. Proc. 9:166. 1956.
257. CHAPPELL, W. E. Control of poison ivy and grass in apple orchards. Down Earth 12:6–7. Summer 1956.
258. DARROW, R. A. Control of post and blackjack oaks by aerial spray applications of herbicides. South. Weed Conf. Proc. 9:109–112. 1956.
259. DAY, B. E. Status of the nutgrass problem in California. Calif. Weed Conf. Proc. 8:125–129. 1956.

260. DUNHAM, R. S., and others. Quackgrass control. Minn. Agr. Expt. Sta., Sta. B. 434, 12 p. June 1956.
261. FISHER, C. E., MEADORS, C. H., and BEHRENS, R. Influence of aerial swath width on control of mesquite with 2,4,5–T. South. Weed Conf. Proc. 9:105–108. 1956.
262. FOY, C. L., and MILLER, J. H. Chemical control of Johnson grass. South. Weed Conf. Proc. 9:197–203. 1956.
263. GT. BRIT. MINISTRY OF AGRICULTURE, FISHERIES AND FOOD. Stinging nettles. Gt. Brit. Min. Agr. Fisheries & Food. Adv. L. 47, amend., 4 p. June 1956.
264. HAUSER, E. W., and THOMPSON, J. T. Progress report on control of established Johnson grass with chemicals and cropping. South. Weed Conf. Proc. 9:190–196. 1956.
265. HAUSER, E. W., and THOMPSON, J. T. Progress report on the differential response of the nutgrasses (Cyperus rotundus and Cyperus esculentus) to herbicides and disking. South. Weed Conf. Proc. 9:211–219. 1956.
266. HERRING, J. H. Shred and rest to control sagebrush. Soil & Water Mag. 5 (7):32. July 1956.
267. HOLLINGSWORTH, E. B., and ENNIS, W. B. Studies on nutgrass [Cyperus rotundus] response to 3–amino–1,2,4–triazole and cultural practices. South. Weed Conf. Proc. 9:204–210. 1956.
268. KIP, H. W. Ragweed control programs and hay fever relief. South. Weed Conf. Proc. 9:254–257. 1956.
269. KLINGMAN, G. C. Wild garlic (Allium vineale) control in a Bermuda grass turf. (Abs.) South. Weed Conf. Proc. 9:231. 1956.
270. KOEHLER, J. W. Whitetop. Calif. Weed Conf. Proc. 8:122–123. 1956.
271. MCCULLY, W. G. Control of post and blackjack oak by the soil injection method. South. Weed Conf. Proc. 9:126–129. 1956.
272. MCILVAIN, E. H. Shinnery oak [Quercus havardii] can be controlled. South. Weed Conf. Proc. 9:95–98. 1956.
273. MEADLY, G. R. W. The thornapples (Datura species). West. Austral. Dept. Agr. J. (ser. 3) 5:289–290, 293–295. May/June 1956.
274. MEADORS, C. H., FISHER, C. E., and BEHRENS, R. Experimental studies with substituted urea herbicides for the control of mesquite and sand shinnery oak. South. Weed Conf. Proc. 9:99–104. 1956.
275. MERESHKO, L. S. Hedge mustard [Sisymbrium officinale] and its control. (In Russian.) Zemledelie 4 (6):122. June 1956.
276. MILLER, J. H., and FOY, C. L. The control of Johnson grass (Sorghum halepense) and Bermuda grass (Cynodon dactylon). Calif. Weed Conf. Proc. 8:119–121. 1956.
277. MILLER, R. K. Control of Halogeton in Nevada by range seedings and herbicides. J. Range Mangt. 9:227–229. Sept. 1956.
278. MORAIS, R. An experiment on the aerial application of herbicides on mountain maple [Acer spicatum]. New Brunswick Internatl. Paper Co. Causapscal Forest Res. Sta. Forest Res. Notes 7, 3 p. May 1956.
279. NILSSON-LEISSNER, G. Flyghavren—en fara för var växtodling [Wild oats—a danger to our crops]. Hushsällsk. Förbund. Smaskr. 20, 11 p. 1956.
280. NORTHERN IRELAND. MINISTRY OF AGRICULTURE. The destruction of charlock. North. Ireland. Min. Agr. L. 38, 4 p. May 1956.
281. OLSEN, H. K. Wild oats once more. (In Danish.) Landbonyt 10:345–347, 350. July 1956.
282. ORCHARD, H. E. Spear thistle (Cirsium vulgare, Ten.). So. Austral. Dept. Agr. J. 59:491–492. July 1956.
283. OWENS, C. B. Chemical eradication of turkey oak [Quercus laevis]. South. Weed Conf. Proc. 9:121–125. 1956.
284. PAGE, T. J. The taming of Typha. Dow Diamond 19 (3):11–13. July 1956.
285. PETERSEN, H. I. Flyvehavren. Vaer på vagt! Bekaemp den! [Wild oats. Watch out. Control it]. København, Landbrugets Informationskontor. 1956. 10 p.
286. POLLOCK, G. N. Rush control in County Fermanagh. North. Ireland. Min. Agr. Mon. Agr. Rpt. 31:77–80. July 1956.
287. PRYOR, M. R. Morning glory: a progress report. Calif. Weed Conf. Proc. 8:116–118. 1956.

288. RAHUDKAR, W. B. The eradication of sanudad (Prosopis spicigera, Linn.). Nagpur Agr. Col. Mag. 30:11–14. 1955/56.
289. RANDALL, C. G. Russian knapweed control. Calif. Weed Conf. Proc. 8: 123–125. 1956.
290. RASMUSSEN, L. W. The effects of 2,4–D and 2,4,5–T applications on the stand density of Canada thistle (Cirsium arvense Scop.). Weeds 4:343–348. Oct. 1956.
291. ROBERTSON, J. H., and CORDS, H. P. Survival of big sagebush [Artemisia tridentata] of different ages after treatment with selective herbicides. Weeds 4:376–385. Ref. Oct. 1956.
292. RUSANOV, F. N. Parasitic plant with beautiful flowers, Phelipaea coccinea Poir. and experiment in growing it. (In Russian.) Moscow. Glav. Bot. Sad. B. 22:86–88. 1955.
293. SARTORETTO, P. A., and CLEARY, W. A. Selective crabgrass control in turf with organo-arsenicals. Agron. Abs. 1956:91.
294. SEARCY, V. S. The control of Cherokee rose (Rosa bracteata) with 2,4–D. South. Weed Conf. Proc. 9:232–234. 1956.
295. SEARCY, V. S. A progress report on the control of wild garlic (Allium vineale) with chemicals. South. Weed Conf. Proc. 9:225–230. 1956.
296. SELLSCHOP, J., and HATTINGH, I. D. Control of nut-grass on lands in the summer-rainfall area. Farming So. Africa 32 (3):49–52, 77–80. June 1956.
297. SILBERSTEIN, Z. The milk thistle, Silybum marianum (L.) Gaertn. Refuah Vet. 13:49. Mar. 1956.
298. STAMPER, E. R., and MELVILLE, G. Studies in the control of nutgrass (Cyperus rotundus). South. Weed Conf. Proc. 9:220–224. 1956.
299. STANESCU, C. Chemical control of dodder [Cuscuta]. (In Rumanian.) Rev. Pădurilor 70:128–130. Mar. 1955.
300. STEVENSON, E. E. Control of morning-glory in lima beans and other crops. Calif. Weed Conf. Proc. 8:105. 1956.
301. TRUCHELUT, G. B., and HUDGINS, H. R. Experiments on the chemical control of wild rose [Rosa bracteata] on the Texas Gulf Coast. South. Weed Conf. Proc. 9:235–236. 1956.
302. VOROB'EV, F. K., and DERIUGIN, I. P. Certain phenol derivatives as a measure of controlling clover dodder [Cuscuta]. (In Russian.) Moskov. Ordena Lenina Sel'skokhoz. Akad. im. K. A. Timiriazeva. Dok. 21:246–251. 1955.
303. WALSH, S. R. Control of wild tobacco tree [Solanum auriculatum] on the Atherton tableland. Queensland Agr. J. 82:331–339. June 1956.
304. WIANCKO, M. R. Test of chemicals for couch grass control. Canada. Natl. Weed Comt. East. Sect. Proc. 9:96–102. 1955, pub. 1956.

C. Biological

305. SMITH, J. M. Biological control of weeds in 1955. Canada. Natl. Weed Comt. East. Sect. Proc. 9:102–103. 1955, pub. 1956.
306. SMITH, J. M. Biological control of weeds. (Abs.) Canada. Natl. Weed Comt. West. Sect. Proc. 9:15. May 1956.

IV. CHEMICAL AND BIOCHEMICAL INVESTIGATIONS

307. JAMES, W. O. The effect of 2,2–dipyridyl on plant respiration. New Phytol. 55:269–279. Ref. May 1956.
308. MITCHELL, L. C. Note on the detection of chlorinated organic pesticides in the paper chromatogram. Assoc. Off. Agr. Chem. J. 39:891–892. Aug. 15, 1956.
309. MORELAND, D. E., and DAVIS, J. C. The effects of certain herbicidal chemicals on the activity of an amylase enzyme—a preliminary report. (Abs.) South. Weed Conf. Proc. 9:150–151. 1956.
310. STUMPF, P. K., and BARBER, G. A. Fat metabolism in higher plants. VII. β-oxidation of fatty acids by peanut mitochondria. Plant Physiol. 31: 304–308. Ref. July 1956.

311. WALKER, R. L., and NEWMAN, A. S. Microbial decomposition of 2,4-dichlorophenoxyacetic acid. Appl. Microbiol. 4:201–206. Ref. July 1956.

V. SPECIAL CHARACTERISTICS OF WEEDS

A. Poisonous Plants and Their Control

312. DONALD, L. G., and SHANKS, P. L. Ragwort [Senecio jacobaea] poisoning from silage. Brit. Vet. J. 112:307–311. Ref. Aug. 1956.
313. FLIGHT, C. H. Lupinosis in sheep. Farming So. Africa 32 (5):37–39. Aug. 1956.
314. HALL, W. T. K. A note on Macrozamia and Xanthorrhoea poisoning of cattle. Austral. Vet. J. 32:173–175. July 1956.
315. KADENATSII, A. N. A new species of the agent of "staggers" in sheep [Setaria marshalli]. (In Russian.) Karakulevodstvo i Zverovodstvo 8 (6):53–54. Nov./Dec. 1955.
316. KLUSSENDORF, R. C. Grass tetany. No. Amer. Vet. 37:743–744. Sept. 1956.
317. KUDRIAVTSEV, B. D. Feathergrass disease of sheep in Kazakhstan. (In Russian.) Veterinariia 33 (8):32. Aug. 1956.
318. MÜLLER, K. Let us prevent poisoning of farm animals. (In Czech.) Za Socialist. Zeměděl. 6:793–797. July 1956.
319. NIKITIN, N. F., and MUKHAMETSHIN, R. Poisoning of cattle with potato leaves. (In Russian.) (Abs.) Veterinariia 33 (8):82. Aug. 1956.
320. SPERRY, O. E. The distribution and control of Texas range plants poisonous to livestock. South. Weed Conf. Proc. 9:142–145. 1956.
321. SPERRY, O. E. Poisonous range plants in Texas. III. Sheep & Goat Raiser 36 (11):48. Aug. 1956.
322. SPERRY, O. E. Poisonous range plants in Texas. IV. Poisonous plants of the caltrop family [Zygophyllaceae]. Sheep & Goat Raiser 36 (12):18. Sept. 1956.
323. SPERRY, O. E. Poisonous range plants in Texas. V–VI. Sheep & Goat Raiser 37 (1):34–35; (2):22–23. Oct.-Nov. 1956.
324. SYLWESTER, E. P. These plants are poison! Capper's Farmer 67 (8):34, 39. Aug. 1956.
325. VALMARI, A. The marsh horsetail—a meadow grass poisonous to animals. (In Swedish.) Beten-Vallar-Mossar 7:96–98. Aug. 1955.

B. Uses of Weeds

C. Pathological & Entomological Relationships

VI. NATURE & PROPERTIES OF CHEMICALS USED AS HERBICIDES

326. ANTOGNINI, J. Vapam—a general soil fumigant. Calif. Weed Conf. Proc. 8:73–75. 1956.
327. BAGLEY, E. HC–1281 or 2,3,6–trichlorobenzoic acid. Calif. Weed Conf. Proc. 8:71–73. 1956.
328. BEATTY, R. H. Progress report on 3–amino 1,2,4–triazole (Amizol). Calif. Weed Conf. Proc. 8:61–63. 1956.
329. CARLSON, A. E. Substituted urea herbicides. Calif. Weed Conf. Proc. 8:30–34. 1956.
330. DAVIS, D. W., and KNOWLTON, G. F. Compatibility chart for pesticide sprays and dusts, and seed treatments. Utah. State Agr. Col. Ext. Ext. C. 245, 4 p. Apr. 1956.
331. DE ONG, E. R. Chemistry and uses of pesticides. Ed. 2. New York. Reinhold. 1956. 334 p. Ref.
332. ERICSSON, G. New herbicides for this spring's fight against weeds. (In Swedish.) Skaraborgs Läns Hushsällsk. Tidn. 4:54–55. June 1956.
333. EVERIST, S. L. Hormone weedkillers. Queensland Fruit & Veg. News 10: 10–11. July 5, 1956.
334. GARCIA CABEZON, A. Los herbicidas selectivos. Spain. Min. de Agr. P. de Capacitación. Agr. Hojas Divulg. 7–56 H, 16 p. Apr. 1956.
335. LENSKÝ, A. The introduction of growth herbicides. (In Czech.) Za Socialist. Zeměděl. 6:784–788. July 1956.

336. MATOLCSY, G., OSWALD, E., and HAMRAN, M. Substituted phenoxyethyl phenoxyacetates as herbicides. (In Hungarian.) Növénytermelés 5:95–106. Ref. Apr. 1956.
337. MAXWELL, K. E. CDAA and CDEC. Calif. Weed Conf. Proc. 8:76–79. 1956.
338. MAZZAN, B. Herbicidas pregerminativos en ajonjoli. Agro [Maracay] 10 (41):31–39. May 1956.
339. OLNEY, V. W. Geigy 444. Calif. Weed Conf. Proc. 8:79–80. 1956.
340. RAKE, D. W. DB granular and ureabor. Calif. Weed Conf. Proc. 8:69–70. 1956.
341. RAYNOR, R. N. Erbon (Baron) and present status of Dalapon. Calif. Weed Conf. Proc. 8:70–71. 1956.
342. RICHARDS, R. F. Field studies of the residual effects of several herbicides. South. Weed Conf. Proc. 9:154–160. 1956.
343. ROBINSON, E. L., and WILLARD, C. J. Ester versus amine; formulation of 2,4–D applied pre-emergence. Down Earth 12 (2):11. Fall 1956.
344. SWEZEY, A. W. Baron, a new residual herbicide. Down Earth 12:15–16. Summer 1956.
345. SZABÓ, K., GÖROG, L., and HAMRAN, J. Synthesis and herbicide effect of aryldithiocarbamic acid ammonium and substituted ammonium salts. (In Hungarian.) Növénytermelés 5:185–192. July 1956.
346. UPCHURCH, R. P., and PIERCE, W. C. The effect of intensity and frequency of simulated rainfall on the leaching of 3(p–chlorophenyl)–1, 1–dimethyl-urea through Lakeland sand soil. Agron. Abs. 1956:94.
347. WARREN, J. C. R., and FULLER, J. C. E. Experimental herbicide 3Y9. Canada. Natl. Weed Comt. East. Sect. Proc. 9:139–141. 1955, pub. 1956.
348. ZEDLER, R. J. Dichloral urea. Calif. Weed Conf. Proc. 8:73. 1956.
349. ZICK, W. H. Factors influencing the effectiveness of maleic hydrazide in controlling quackgrass, Agropyron repens. Diss. Abs. 16:784. Apr. 1956.

VII. EFFECT OF HERBICIDES ON SOILS, LIVESTOCK & HUMANS

350. CHANCOGNE, M., and CATELOT, C. Etude de l'efficacité insecticide des mélanges du M.C.P.A. avec le H.C.H. ou le parathion. Phytiatrie-Phytopharm. 4:143–146. Sept. 1955.
351. CONN, L. A. Weed-free sludge beds. Water & Sewage Works 103 (ref. & data no.):R318–R319. June 15, 1956.
352. IVARSON, K. C., and PRAMER, D. The persistence and biological effects of surface active agents in soil. Soil Sci. Soc. Amer. Proc. 20:371–374. July 1956.
353. ROGOFF, M. H. Bacterial decomposition of synthetic hormone herbicides. Pa. State U. Abs. Doct. Diss. 17:117–119. 1954, pub. 1955.
354. VOROB'EV, K. F., and ABUEVA, A. A. Weed control by placing herbicide in the soil. (In Russian.) Moskov. Ordena Lenina Sel'skokhoz. Akad. im. K. A. Timiriazeva. Dok. 21:234–239. 1955.
355. WAHLSTROM, R. C., KAMSTRA, L. D., and OLSON, O. E. The effect of organic arsenicals, chlortetra-cycline and linseed oil meal on selenium poisoning in swine. J. Anim. Sci. 15:794–799. Ref. Aug. 1956.

VIII. EQUIPMENT, METHODS OF APPLICATION, AND HERBICIDAL CALCULATIONS

356. ABELL, C. Butane drives largest land clearing machine. Butane-Propane News 18 (8):127–130. Aug. 1956.
357. AKESSON, N. B., CURLEY, R. G., and YATES, W. E. When you buy or build a field sprayer. Calif. Weed. Conf. Proc. 8:150–155. 1956.
358. BURKHARDT, G. J., and DITMAN, L. P. An improved spray boom for row crops. Canning Trade 79 (6):7, 20. Aug. 27, 1956.
359. CAMPBELL, L. G. Short notes on some spraying machines. Agr. Soc. Trinidad & Tobago. J. 56:135–138. Mar. 1956.
360. COURSHEE, R. J. A pocket calculator for small volume spraying. J. Agr. Engin. Res. 1:143–149. Ref. 1956.
361. DERSCHEID, L. A., and DELONG, H. H. Weed control equipment. S. Dak. Agr. Expt. Sta. C. 125, 20 p. Apr. 1956.

362. DEWERTH, A. F., and JASKA, R. C. Greenhouse cooling. South. Florist & Nurseryman 69 (23):11–15, 24–25. Aug. 17, 1956.
363. KEARNS, H. G. H., and MORGAN, N. G. Spray application problems. XXVIII–XXX. Bristol. U. Agr. & Hort. Res. Sta. Annu. Rpt. 1955:146–158. 1956.
364. KLINNER, W. E. Explosives in the service of agriculture. J. Agr. Engin. Res. 1:172–174. Ref. 1956.
365. KOCH, H. Anerkannte pflanzenschutzgeräte und -geräteteile. I. Nachrbl. des Deut. Pflanzenschutzdienstes 8:81–86. June 1956.
366. MADER, D. L. Use of forest humus to reduce the toxicity to tree seedlings from insecticides, fungicides, and herbicides in the soil. Agron. Abs. 1956:51.
367. MEISAKHOVICH, IA. Raising the efficiency of the tractor sprayer. (In Russian.) Mashinno-Traktornaia Sta. 16 (6):30. June 1956.
368. MILLER, P. M. Use of hypodermic syringe and needle as an atomizer. Plant Dis. Rptr. 40:755. Aug. 15, 1956.
369. MORAWETZ, J. E. La lucha contra las plagas. Rev. Nac. de Agr. 50 (615): 12–16. (Cont.) July 1956.
370. MORGAN, G. Corrosion resistance and transfer equipment termed vital for good farm sprayer. Cotton Digest 28 (50):32. Aug. 25, 1956.
371. PAGE, G. E. Plot and laboratory sprayers. Calif. Weed Conf. Proc. 8:147–149. 1956.
372. PELEJ, J. Agricultural spray nozzle design, research and manufacturing. Calif. Weed Conf. Proc. 8:129–134. 1956.
373. RAVENSBERG, K. Comparison of the knapsack sprayer and the knapsack mist sprayer for disease control. (In Dutch.) Boskoop. Ver. Proefsta. v. de Boomkwekerij. Jaarb. 1955:87–88.
374. SCHUTZ, H. B., and others. Drift of 2,4–D applied by plane. Calif. Agr. 10 (8):4–5, 14. Aug. 1956.
375. SEXSMITH, J. J., and ANDERSON, D. T. Aerial spray trials. I–II. Canada. Natl. Weed Comt. West. Sect. Proc. 9:6–10. May 1956.
376. STEARNS, C. R. Mechanical spraying equipment and spraying operations. Citrus Mag. 18 (12):21–22. Aug. 1956.
377. THOMAS, C. H., and PORTER, W. K. Development of machines for application of experimental chemicals. South. Weed Conf. Proc. 9:242–244. 1956.
378. THOMPSON, J. L. Standardization of plot sprayers. Canada. Natl. Weed Comt. West. Sect. Proc. 9:13–14. May 1956.
379. VENGRIS, J., and THOMSON, C. L. Chemical weed control equipment. Mass. U. Agr. Ext. L. 297, 8 p. June 1956.
380. WASHBURN, B. Ground sprayers. Calif. Weed Conf. Proc. 8:145–147. 1956.

IX. LEGAL ASPECTS

381. GORDON, C. M. Farmer's viewpoint. Calif. Weed Conf. Proc. 8:88–90. 1956.
382. HOWIE, R. M. The regulatory phase of weed control in California. Calif. Weed Conf. Proc. 8:86–88. 1956.
383. WHEELER, W. H. The exportation of plant materials. Plant Dis. Rptr. 40:666. July 15, 1956.

W. F. HUMPHREY PRESS INC.
GENEVA, N. Y.

Suggestions for Contributors to WEEDS

Manuscripts dealing with all aspects of weed control, regulatory, educational and research, are accepted for publication in WEEDS. Manuscripts should have more than purely local interest. The material described should be more conclusive than progress reports. Articles must be original material previously unpublished elsewhere. Prior publication in brief abstract form is permitted. After review, each manuscript will be accepted for publication upon recommendation of the Editorial Board. The author has the opportunity to make revisions after the review is completed and before publication. Refer to a recent issue of WEEDS to determine details of style to be used.

Manuscripts. Two copies, one on bond paper, should be furnished for each manuscript. The entire text should be double spaced. An additional copy of the manuscript should be retained by the author to ensure against loss.

Use as short a title as practical. Following the title give the authors name(s). It is desirable to divide the manuscript into sections with headings such as Introduction, Methods and Materials, Results, Discussion, Summary and Literature Cited. Avoid underscoring headings, words or phrases unless you wish them to be printed in italics.

Measurements such as time, weight and degrees should be in arabic numerals regardless of the number of digits in the number. Where the figure is not one of measurement, figures below 10 should be spelled out except when one figure in a series has two digits in which case all should be in arabic.

All chemicals mentioned should be described fully the first time used. Nomenclature, abbreviations and definitions should follow those presented in the Terminology Committee Report, WSA, published in WEEDS 4:278-284, July, 1956.

Footnotes. Use footnotes sparingly for items that cannot be included conveniently in the text. The place where the study was done and the address of the author(s) should be given as footnotes. Number footnotes to the text consecutively throughout the manuscript with superscript arabic numerals. Designate footnotes to the tables with superscript lower case letters.

Figures. Experimental data may be presented in graphic or tabular form. However, figures should not be used if they merely illustrate material presented in the text or in tables. Prepare illustrations with approximately the same proportions as a printed page, $4^3/_4$ x 7 inches, or some fraction of a page. Photographs should be clear glossy prints and should be trimmed of unessential portions.

Graphs and drawings should be inked with heavy black lines to ensure clarity after reduction in size. Hand lettering should be large and made with a lettering guide. Typing is not acceptable. Place the author's name and figure number of the back of each one submitted. Type the legend for each figure on a separate sheet. Figures should be numbered consecutively in arabic numerals.

Tables. Type each table on a separate sheet. Tables should be numbered consecutively in arabic numerals in order of reference in the text. In tables, the caption, column headings and side headings should be in lower case with only the first word and proper nouns capitalized.

Citations. Citations are numbered alphabetically by senior author and the number of the reference is used in the text. Citations should include names of all authors, complete title, volume number, inclusive pages, publication and year. Theses and letters, or any other communication not readily available in libraries, should appear as footnotes.